AN

ELEMENTARY TREATISE

ON

STEAM,

MORE PARTICULARLY AS APPLICABLE TO THE PURPOSES OF

NAVIGATION,

WITH A

FAMILIAR DESCRIPTION OF THE ENGINE;

Shewing the manner of its management in giving the Rotatory Motion; how started, eased, and stopped; the Nature and Properties of Steam, on both High and Low-pressure principles; its introduction into, and discharge from, the Cylinders, illustrated; as, also, how to ascertain the quantum of Actual Pressure at which the Engine is working; and the manner of Condensing Steam explained; together with a General Account of the operations of the Engine-Room; shewing the Accidents to which Steam Boilers are liable, and means of prevention; and, further, the Economy of Coals, how to be effected, &c. &c.

BY ROBERT OTWAY,

COMMANDER, R. N.

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DEDICATED

TO THE

RIGHT HONORABLE LORD JOHN HAY,

CAPTAIN, R.N. &c., &c.

MY LORD,

Your Lordship being the first essayist in the novel and most efficient mode of conducting war on an enemy's coast, through the medium of Steam Vessels, it is with peculiar pride that I venture to dedicate the following Treatise on Steam Navigation to your Lordship, as an Officer practically conversant with the importance of the subject; and, perhaps, more capable than any other of appreciating the vast advantages derivable from the aid of Steam Vessels in maritime warfare, on occasions especially when it becomes an object of moment that troops be transferred from place to place with celerity, and, at the same time, in full vigour for instantaneous co-operation, so soon as arrived. Your Lordship's experience, during the contest on the North coast of Spain, will amply bear out the fact as exemplified on various occasions; particularly on the momentous morning of the 5th of May, 1836, when the opportune arrival of a reinforcement of 1500 fresh troops from Santander, by one Steamer alone, the Salamander, which your Lordship had dispatched the day before from San Sebastian, a distance of 100 miles, for that express purpose, gave a decisive and important turn to the transactions of that day; those additional

troops having joined in the action within a few minutes after landing;—a consummation which could not have been accomplished through any other medium. These are results, emanating from Steam communication, which the arduous and anxious position in which your Lordship was frequently placed, qualifies you fully to appreciate; having had the whole direction of maritime operations along an extended line of coast, during the time that civil war devastated the Northern Provinces, and, upon occasions too, requiring reinforcements at, or from, distant positions, on sudden emergencies, when the intended operations of the Insurgent party only became known a few hours prior to a decisive movement on their part. Such was the position in which your Lordship frequently found yourself; yet, such was the aid derivable from the resources of Steam communication, that half the anxieties which, under other circumstances, would have been scarcely supportable, owing to the very limited number of troops for the defence of so long a line of country, were dissipated by a confidence in timely arrivals, despite the remoteness of distance. In any future active war, these vessels must constitute the post of honor.

I have the honor to be,

My Lord,

Your Lordship's most obedient

And very humble servant,

ROBERT OTWAY, Commander, R.N.

PREFACE.

IN a work of this nature, it is I trust, justifiable in one, who like myself, is not a professed Engineer, to borrow sentiments from others, if in unison with his own ideas, whensoever the language, in which the descriptions are clothed, appears more concise, or better expressed, than that he himself had previously adopted. That this is my case, I not only admit, but moreover would willingly express the obligations I am under to the individuals themselves, did I recollect the authorities from whom I have, from time to time, made extracts, whilst engaged in the study of the nature and properties of Steam. These, however, are not numerous, and will be readily detected by the difference of diction; but I write not for the eye of criticism, nor for the finished mechanic,

but solely as a sailor, and for the sailor; at the same time practically, as having dedicated my attention, for a series of years, to the management of the Engines, Boilers, Furnaces, &c. to the exclusion of theoretical analysis. For my aim has been to impart a knowledge of that branch of Steaming which applies more especially to Navigation, and to give to my brother Officers an insight into the duties, in as far as Steam operations are concerned, which immediately devolve on them. To this end I have condensed the various heads, under which I have treated the subject, into the most compact form; at the same time *advisedly* had recourse to occasional repetition: for as the science of Steaming in a professional point of view, as blended with the sea service, is to Naval men new, it has been thought to be particularly desirable that striking passages of import should be repeated as opportunities offered, so as to better fix the attention.

An Essay upon such a science must necessarily be a bold undertaking in one whose education has been grounded on a widely different basis; and will, I trust, meet indulgence from those more competent to the task,

but whose want of leisure precludes the undertaking. My chief motive for thus venturing in the field of literature is, that I am fully aware how much an *elementary* work of this kind is in request, having experimentally felt the want of such at the commencement of my own studies; those previously published works, which treated on the subject of Steam, so far from proving familiar and *elementary*, were written in a style adapted to proficients, and treating on the subject in terms so technical and scientific, as to render it altogether abstruse; as well as filling page after page with elaborate details of the origin, and progressive advance, of steam, instead of entering at once into the practical uses of this stupendous power.

Although the present work is designated a *third edition*, it is in point of fact a new work, but upon the former basis; the two first having been got up under hurried circumstances during a period of active employment—pending the civil war in Portugal; notwithstanding the want of such a help for beginners, in the study of Steam navigation, was so much felt, that those editions, defective as they were, met with a reception sufficient to

induce me to renew my efforts since being upon half-pay, as *time* has thereby been afforded for putting forth an improved copy, which, I trust, will be acceptable; and as appropriate diagrams, in books of science more particularly, (as an impressive variety most likely to fix the attention) I conceive to be very essential, I have been no way sparing in dispersing them throughout this work; and, that no difficulties should be experienced by even the most uninitiated, illustrative drawings of each separate portion of the Marine Engine have been attached to the *margins of the written descriptions* under their several heads (and not collected in separate sheets for reference); and, eventually, combined together in a general view of the Engine. One line of engraving, I take to be worth a dozen lines of letter-press in the way of elucidation.

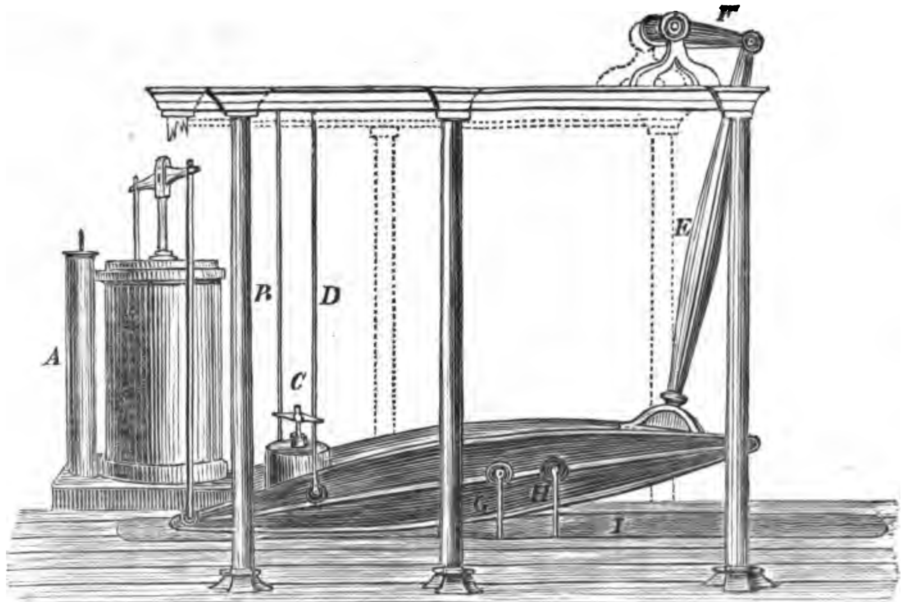
This present edition will be found to contain, among other useful matter, an explanation of the rotatory motion of the wheels, how imparted; manner of starting the Engines; easing, and stopping, them; the nature and properties of Steam,—both on high and on low pressure principles,—shewing the manner of its introduction into the cylinders at top and bottom; the strength of Steam

within the cylinders, how ascertained; shewing how the power of the same Engines may be increased or diminished, as required; condensation of Steam, and its exit from the cylinders for the formation of a vaccuum, explained; generating Steam, and the principles on which the phenomena of heat depend; observations on the defective build of the present classes of Steam Vessels, and sailing a Steam Vessel; also, general management of Steamers under canvas in fine weather, in trade winds, and in heavy gales, &c.

The plates will be descriptive of the several portions of the Engine; as also diagrams of the interior of both the cylindrical or high-pressure boiler, and the square or low-pressure boiler, shewing the circulation of the fire-heat, and the protection of the flues from getting burnt, &c.

In advocating the principles of modified "High-pressure," I am aware that to conquer prejudice is a sufficiently difficult task; but to overcome the machinations of envy and jealousy is indeed Herculean labour. Notwithstanding, science, when indisputably demonstrative

of superior results through improved systems, however opposed for a time, by interested competitors, must eventually shine forth in the splendour of those benefits which it purposes to bestow. Such will be the progress of "Expansive Steam," opposed, as it has been, not by prejudice, (for Engineers are fully alive to its superior advantages) but objected to because its application to the rotatory principle of the paddle wheels of a Steamer, and its introduction on board ship, have been the work of others, deemed, by them, incompetent to the task, if not even presumptuous in having attempted it. I predict, however, that the day is not distant when its application on board Steamers will become general; and as a first step in this advance, we find, that of late, even low-power steam has been "expanded" within the cylinders. But to shew the vast economy of applying moderately high-pressure steam, one fact, (and in regard to Marine Engines perhaps the only one) will suffice: The Echo's Engines of 50 horse power each, which under the old system of square boilers, and 3½lbs steam, per square inch, consumed from twelve to fourteen bushels of coals per hour, were afterwards worked, "on the principle of Expansion," with steam of 15lbs pressure,



A Slide
B Side Rod
C Air-pump and Rod
D Side Rod
E Connecting Rod

F Crank
G Feed Pump
H Bilge Pump
I Bilge

RUDIMENTS, OR OUTLINES, OF A MARINE ENGINE, OR LAND ENGINE REVERSED.

at an average of from seven to eight bushels only per hour, and doing precisely the same duty as before; in other words, diminishing the expenditure by 160 tons of coals, per month,—that is to say, reducing it from 9500 bushels, down to 5000 bushels, a month, and thus realizing a saving of one half the former consumption. But on the mines in Cornwall, (where alone, by the bye, *economy in fuel* seems to be studied) the saving of coals, since this application of steam, has amounted to *four thousand bushels out of six* (see "Cornish Mines") in each succeeding month! That modified high-pressure used "Expansively," as it is in Cornwall, should not meet general adoption seems incredible, to the same extent as does the amount of coals saved, yet such is fact, and such the force of prejudice. For, biggotted as the "Low-pressure" candidates may be, they cannot but admit that Cornish miners are fully as conversant with the nature and properties of Steam, as any other set of men in the kingdom; almost every improvement in the science having emanated from among them: and, moreover, that they are not men to wantonly throw away money in fostering a new *hobby* without good and adequate reason.

When Steam Navigation first became a branch of the Naval profession, all knowledge of the management of the Engines, the application of Steam power, &c. was confined to the Engineers, to whom the working of the Machinery was entrusted. These men I found, almost invariably, solicitous to evade, by technicality of language, imparting information on the subject; and, in fine, to use every endeavour to make a mystery of the whole operations of the Engine room; either with a view to maintain a mastery over the officers, to whom they were legitimately under obedience; or, as is too often found among persons who pride themselves on an imaginary excellence, with that of enhancing the value of their services, by inducing a belief that the peculiar art they profess, requiring a superior genius, ought to be confined to a few. SIR JOHN HERSCHEL has remarked that "the tendency of *empiric* art is to bury itself in technicalities, and to place its pride in particular mysteries, known only to adepts; to surprise and astonish by *results*, but to conceal *processes*. Whereas the character of science is the direct contrary; it delights to lay itself open to enquiry; and is not satisfied with conclusions, until it can make a road to them broad and beaten; and in its application,

it preserves the same character; its whole aim being to strip away all technical mysteries, to illuminate every dark recess, and to give free access to all *processes.*"

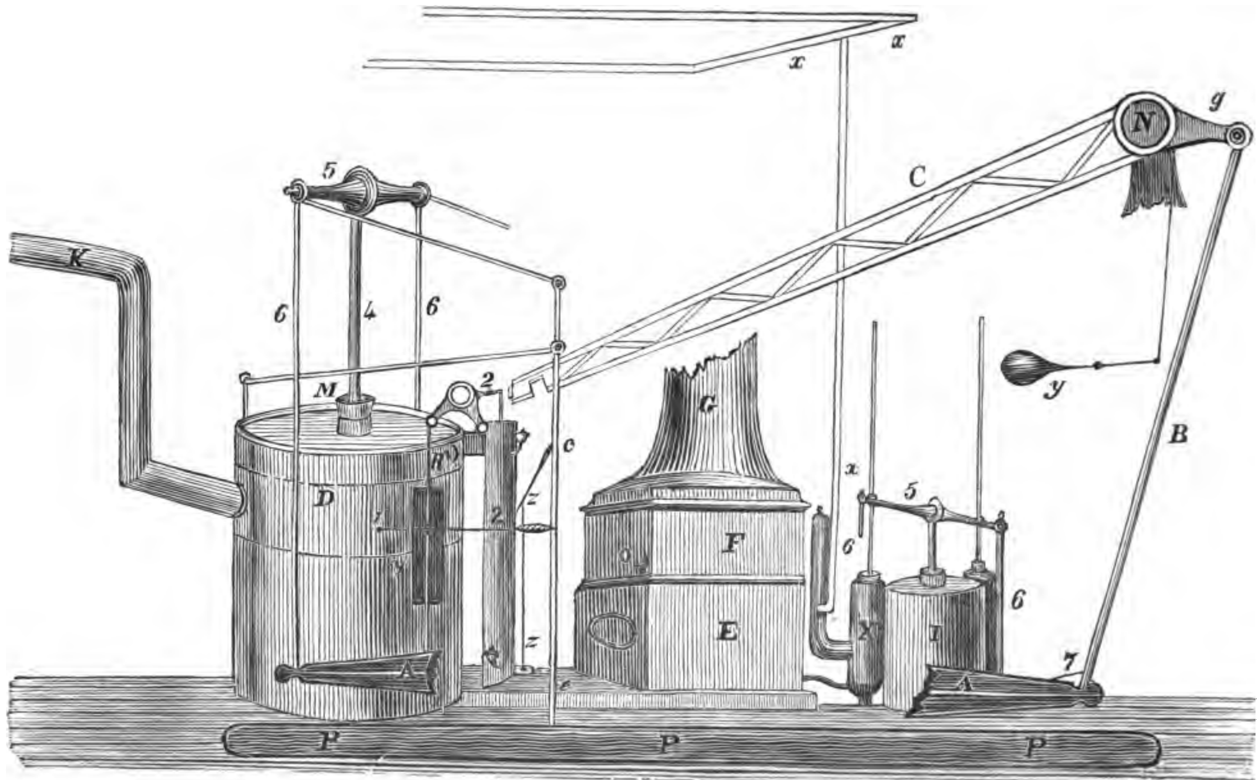
It was with a view to counteract this empiricism—this mystification, that the following Treatise first owed its origin; for a length of time prior, and subsequent to, my obtaining command of a Steam Vessel, I had labored hard to get a "peep" into the science; but jealousy was for a length of time proof against reward or entreaty; at length, when success did crown my efforts, I was resolved to profit by it myself, and to open the door to my brother Officers; and what I have eventually learnt is now imparted for their benefit, and for that of every individual, in the community at large, who feels an interest in Steam operations.

If the plan of occasional repetition, which I have in this Edition adopted *by particular request,* should be objected to, I have only to observe in extenuation, that it has ever been found that "repetition" has a powerful influence on the memory, and is the most effectual

means of inducing lasting impressions; for which reason alone has it been had recourse to.

A Land Engine, being less complex than a Marine Engine, is easier to be comprehended, and has therefore been selected as an appropriate Frontispiece, accompanied at the same time with a representation of the skeleton of a Marine Engine, which, in its simple state, differs but little from the Land Engine *reversed.*

Finally, I beg to observe that whatever remarks may be found interspersed in this work, have for their object the pointing out changes which may be made with advantage, and not with the view of finding fault, either with persons or systems.



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COMET'S ENGINE WITHOUT THE FRAMING.

A The two ends of the Sway Beam, centre left out
B Connecting Rod
C Eccentric Rod, out of gear, but to fit on the clutch 
D Cylinder
E Condenser
e Eduction Pipe
F Hot water Cistern
G Cone or Air tube
I Air Pump
K Steam Pipe
M Stuffing Box and Gland
N Shaft for working the wheel
O Injection Cock

P Bilge
R Throttle Valve
1 The Starting Lever
2 Slide Valve, with Grease Cups, worked by Eccen- Rod
4 Piston Rod
5 Cross Head
6 Side Rods of Cylinder and Air Pump
7 Forkhead, not visible
9 Crank of the Shafts, worked by the Eccentric
c Parallel Motion Rod
z Blow-through Valve
y Counterpoise of D slide and of Eccentric Rod
x Feed Pump and Pipes

STEAM NAVIGATION.

THIS being a new branch of our Naval profession, and many erroneous notions relative to the qualification of Officers, destined to command vessels which are conducted on this principle, having been entertained, I beg to offer a few observations to those of my brother Officers who are candidates for such appointments, with a view of shewing that the difficulties apprehended, and the complexity so much dreaded, do not consist in the appropriation and judicious direction of the power they have to deal with—that is Steam; but that such attaches to the Steam Engine only, with which the Commanding Officer has comparatively very little to do. For the sundry duties which divide his attention render it altogether impossible that he can superintend both on deck, and below in the Engine-room, at the same time. How,

for instance, can he venture to quit the deck at the time that his vessel is passing through the intricacies of a narrow channel, or through a dense mass of shipping, coming to an anchor, &c.? It would be attended with a risk involving his commission. Besides, attention to the Engines must be unceasing; and for this reason it is that two or three Engineers are attached to each vessel, to relieve each other in succession; and under their management must the Engines be placed.

I purpose in the following pages to point out the actual duties which, in regard to Steam operations, really attach to the Commanding Officer; to shew how far it is incumbent on him to acquire a knowledge of the mechanism of the engine itself, and the principles on which it acts; for it is most certainly essential, that an acquaintance with the principles on which steam agency is conducted, to a certain extent, should be acquired by every individual connected with Steam operations; and is indeed imperative, as a check upon those persons under him; as also on others whom business may bring him in contact with. Contracters and Engine Makers sometimes see flaws in the machinery, which Commanding Officers know to be of no consequence.

To attain this acquaintance of the Steam Engine, by no means requires the probationary apprenticeship at

the forge of a factory; on the contrary, such a probation would be but a loss of time; and however well intended, a laborious drudgery to no profitable end. To build a Steam Engine, or even to erect one, is no part of the Commanding Officer's duty; though, by all means, it is advisable that he superintend its erection when being placed in the vessel; neither is it required of him to crawl through a boiler, in order to see a patch put on, when circumstances render such an operation necessary: and, furthermore, were he ever so able a Machinist, his skill, in the event of breaking a piston or side rod, would avail him nothing; for his resource must be the factory at last; wherefore it is no more essential that an Officer, because he aspires to command a Steam Vessel, should be a blacksmith, than that another, whose ambition is to be entrusted with that of a frigate, or line of battle ship, should be a carpenter. The science of ship-building is one thing, that of navigating a ship another. The same applies to the operations of Steaming. Not that I mean to imply that a knowledge of any science, much less that of Mechanics, is to be treated with contumely; on the contrary, by a competent acquaintance with any branch of Mechanics, aided by a fertile genius, very beneficial results may be hoped for from the Officer who has practical operations passing daily under his view. But unless a mechanical genius is inherent, no labour can lead to its acquirement; I merely mean to infer, that

such mechanical attainments are not indispensably requisite on the part of those whose connexion with their destined purposes is solely that of turning their efficient power to the most profitable ends.

Speaking generally, I may say, the science of Engineering is the province of the Engineer alone: and were any argument required to shew the inutility, and utter fallacy, of an Officer's dedication of himself, for a few months only, to the routine of a Factory, with the hope of issuing forth a finished Engineer, I can only say that I have the word of one of the first Engineers and Engine-makers in the kingdom, that from among the many hundred persons employed in his establishment, from early youth to the vigour of manhood, there are not more than four or five individuals whom he could pronounce to be "Engineers." But, notwithstanding this, although we cannot all of us aspire to the preeminence of "men of science," we are nevertheless not to be discouraged from acquiring some insight into the system of Steaming, if we purpose commanding a vessel of that description: it is the duty of every Officer on board a Steamer to render himself acquainted with the component parts of the Steam Engine; with the nature and properties of Steam; the economic use of fuel; and in fine, with every thing connected with the Engine-room; to this end he may rest assured, that a six or eight

weeks' voyage on board a Steam Vessel, provided he bends his attention to the subject, and is indefatigable in his attendance in the Engine-room, aided by some such simple explanatory details as I purpose here to offer to his notice, will give him a far greater insight into the whole system, especially as applied to Navigation, than he could obtain in as many months of laborious drudgery in the Foundery.

I have been led to these remarks, from having heard of Officers who, with a very praiseworthy zeal, have actually wielded the sledge hammer, in certain Factories of celebrity, in the Steam Engine department. But such persons must not run away with the notion, that it is the superintendence of the Engines of a Factory, by which they are to attain a knowledge of those operations necessary for Ship-board. For although a rotatory action is established for certain purposes in Manufactories, yet the principles are widely different from the rotatory movement of the paddle wheels of a vessel. The Land Engine is adapted for turning mill-work, &c., the action of which is given to the spindles, and apparatus, by means of a rod working from the axis of a fly-wheel; which fly-wheel is essential for carrying the crank over the centre, (that is, over the line of perpendicular) for the performance of the rotatory motion; whereas on board

ship this movement is attained by means of a *double set* of Engines, the crank of the one being placed at right angles, or 90° from the other; each in turn aiding thereby the other when passing the centre. Besides these engines for rotatory motion, there are *atmospheric* Engines likewise in use; the piston of which is forced *upwards* by steam, and the downward stroke is effected by the weight of atmospheric pressure alone, and not by the force of steam, as in the double *acting* Engines (not double *set*, as these are double acting also).

These single-power Engines, which are used on shore, generally for pumping water from mines, have the steam admitted only on the under side of the piston, the returning stroke being made by the counter-weight, instead of the continuous equable supply of steam. There are advantages moreover, attainable on shore, which cannot be transferred to a ship. One or two persons are fully sufficient to superintend a shore-engine, feed the fires, &c., but on board a steam-vessel the labour is great, and the attention required unceasing; the feeding of the fires moreover is repeated at short intervals, the fuel being supplied in small quantities. I have seen engines of the greatest power, ninety inch cylinders, attended by a man and boy only, for twelve successive hours, without fatigue to them. An occasional shovelful of coals, supplied twice or

thrice in the hour, amply sufficed; but then the boilers, being set in mason work, were excluded from the action of atmospheric air, and at the same time afforded a greater extent of fire-surface; the fire-heat, the flame, after passing through the centre of the boilers, by means of the flues, next circulated round the outsides; so that a considerable saving of fuel is effected, which, in this particular, cannot be adopted on board.

That Steam is a powerful agent capable of rending the strongest materials, is certainly fact; but the Commanding Officer of a Steam Vessel has no need to be affrighted at this,—all that is required of him is common-place prudence and attention; and neither too implicit confidence in those immediately attendant on the Engines, nor too rash an application of Steam for the mere purpose of *shewing off*, by an acceleration of speed, or, the very censureable, competition with a rival Steamer.

The Boilers and Engines are calculated, in point of strength, to perform certain duty; and the safety-valves are loaded* in proportion; and, even in the event of

* If the evolved heat be prevented from escape, by additional weights (or pressure) on the valves, the expansive force is thereby increased till it *counterbalances* the pressure, and thus proportionally increases its volume to the hazard of the containing vessel; the same effect is produced by increasing the temperature by fresh accessions of caloric, and neglect in regard to keeping up an adequate supply of Feed-water.

accident, should the latter not lift, when the steam may have attained a superior elastic force, beyond what the load is calculated to restrain, by attention to the *steam guage*, affixed to the jacket of the cylinder, the presence of danger may always be detected, as the thermometer invariably indicates the pressure of the steam at which the Engine is working: hereby any inaccuracy of the safety-valves is immediately pointed out.* The strength of the steam is thus ascertained: if the quicksilver in the thermometer rises, say one inch upon the graduated scale, caused by the pressure of steam within the boilers, it shews that there is one-half pound pressure per square inch against the inner side of the vessel containing it, tending in that proportion to burst it; for if the section of the pipe of the thermometer were just one superficial inch, the pressure would be supporting one cubic inch of mercury, which will be found to weigh near half a pound.

It is only when steam becomes too highly rarefied that

* The indicator or water gauge should occasionally be shaken as corrosion sometimes occurs, in which case the index remaining *fixed*, induces a belief that the water and consequently the steam, is higher than it really is, and the Engineer is induced to open the fire doors to let it down; when, all of a sudden, the Engines perhaps stop, for *want of steam* through an intended precaution that it does not get too high, instead of the precaution of "not placing too great confidence in the indicator." See Article "Safety Pipe."

any thing like danger need be apprehended; and that on ship-board only, where, from the unavoidable motion of the vessel, the water within the boilers is at times predominant either at one end or the other. It is therefore I think, very questionable, whether at such times the steam is not compressed by such sudden transition of water, into a small compass, instead of acting equally on the whole surface throughout, as it would do if the water were quite still. This conclusion I have drawn from having remarked that, under such circumstances of undulation, the effect produced was the gush of steam from the escape valves. A regulator might be introduced within the steam pipe, which would proportion the quantity of steam to be admitted into the cylinder, in accordance with the plunging of the vessel; so long as she continued on an even keel, the regulator would hang perpendicular; and as she plunged, it would close the steam pipe in the same ratio, and prevent a superabundant gush of steam.

Cylindrical Boilers would obviate all apprehension, as they are capable of sustaining the utmost pressure. But lest any misapprehension should exist relative to danger from *modified high-pressure,* such as was used in the Echo, Steam Vessel, 15lbs to the square inch, I beg to

observe, that even though thrown into the cylinder wholesale, that is without wire-drawing it, or cutting it off at any given portion of the stroke, steam of this power would have little other effect than that of accelerating the velocity of the pistons. Wire-drawing, I should observe, is the progressive opening of the valves for the admission of steam into the cylinders. That there exists a *possibility* of injuring the pistons, or cylinders, is true, but barely so; however, as this possibility does exist, prudence dictates the propriety of caution on this point, and of inducing the Engineer to proportion his steam to the duty required of the Engine.

One great benefit to be derived from high-pressure steam, is *economy;* for after it has attained a certain temperature, it requires but very little coal to maintain a sufficiency of fire-heat to continue it at that temperature; and consequently at the same power, or elastic force. Owing to its great elastic force, *less* steam is required to be employed within the cylinders; and in this consists the whole secret of "economy of fuel," for the saving of steam* is the saving of fuel. If this steam be thrown into the cylinders wholesale, we waste steam, because it is not required, and a waste of fuel follows; for it is

* The benefit to be derived, consists in cutting off the steam at a given portion of the stroke, and saving the remainder.

evident, that the more steam we can *reserve*, the less need is there of forcing the fires with additional coal, in order to raise further supplies: and vice versa, if we are unnecessarily lavish in the expenditure of it, we must generate more at a further expenditure of coals.

But whether high or low power be used, what the Commanding Officer has principally to attain is, a thorough knowledge of the uses of the thermometer affixed to the steam jacket of the cylinder; of the barometer attached to the condenser; the names and destinations of the various parts of the Engine; how each acts, or is acted on; what affinity one portion bears to another; the manner of motion, how imparted to the piston, connecting rod, crank, shafts, and paddle-wheels. How the Engine is started or set going; the acceleration, retardation, and stoppage of the Engine; the backward and forward movement, how given. The nature and properties of Steam; its introduction into the cylinders at the top and bottom, for the double action (which for the propelling of vessels is neccessary) as the operating cause of the rise and fall of the pistons. Also the uses of the air-pump, condenser, feed-pumps or plungers; and finally the judicious feeding of the furnaces, and the consequences of irregularity therein, as effecting the consumption of fuel; for on these latter points very much depends whether economy, or un-

neccessary expenditure shall accrue, by the manner of supply.

With a view to this necessary acquirement, we will proceed in this early stage, to define the sundry parts of the engine, prior to entering on the discussion of the properties of steam, with the mode of management, &c.

THE STEAM ENGINE.

The whole process of the movements of the Engine may be said to be dependent on three primary causes, viz.—the steam from the boilers into the cylinders; secondly, the effect of this steam as giving motion,* upwards and downwards, to the pistons within the cylinders, and which impart a simultaneous movement to the connecting rods; and thirdly, the connecting rod; which not only conduces to the rotatory motion of the

* The force with which the piston is driven up, or down, when there is a vacuum on the opposite side, is as the square of the diameter of the base of the cylinder, that is, it will ascend or descend with four times the power in a cylinder of 2 inches ($2\times2=4$, the square) greater than it would in a cylinder of 1 inch; for the areas of circles, are as the squares of their diameters; and consequently for a cylinder of 40 inches, it will be $40\times40=1600$ times the force above that of a 1 inch cylinder, and be equivalent to about 20,000lbs pressure instead of 15lbs. By the same rule of proportion, if the descent and area of the piston were to be doubled, the power of the Engine would not be doubled only, but quadrupled.

crank shaft, and consequently to the paddle-wheels, but also feeds the pistons within the cylinders (upon which the connecting rod itself was first dependent for motion) with fresh supplies of steam, through the agency of the eccentric rod and slide valve, which it works. The piston first giving motion to the connecting rod, and afterwards depending upon the connecting rod for its own movement.

Steam Engines are worked by the *single* and by the *double* action, according to the purposes for which they are required; for pumping water, and draining mines, the single action will suffice; the down stroke of the piston being performed by the weight of atmospheric air—whereas for rotatory movement of the paddle-wheels of steam vessels, the double action, that is the action of steam both above and below the piston, is indispensible; and it is this we purpose to explain.

DENOMINATION AND USES OF THE SUNDRY PARTS OF THE MACHINERY, WITH REFERENCES TO THE GENERAL DIAGRAM OF THE ENGINE.

LENGTH OF STROKE.

The length of stroke, is the movement of the piston

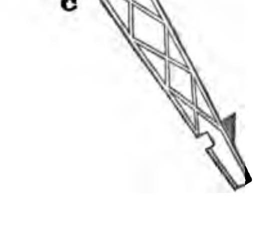
and rod, upwards and downwards, within the cylinders (consequently *double* the length, or depth, of the cylinder) during the time the crank shaft, (No. 9) which is at the opposite end of the sway beam (8) is making one complete revolution; wherefore, in calculating the power of an engine, although the length of the cylinder only is given, this double movement must be allowed for; thus a 4 feet stroke, means a cylinder of 4 feet in length, (exclusive of an allowance for the piston) this by the table (see Article "Horse Power,") gives 25 as the number of revolutions in a minute; which, for a 4 feet stroke, would be $4 \times 25 = 100$ feet, as the distance the piston had travelled in that time; but the stroke being *double the length* of the cylinder, we double the distance travelled, and call it, as per table, 200 feet.

SINGLE AND DOUBLE ACTING ENGINES.

For the purposes of Navigation, the *double acting* engines for the application of steam above and below the piston, are indispensible; and of these we shall treat in the following pages. For pumping water out of mines, &c. the single acting engine will suffice; and if the steam be introduced below the piston, atmospheric air acts upon the top of it, and not steam; and a jet of cold water is made to pass upwards within the cylinder, as soon as the

piston reaches the top, by the opening of a cock for its admission, at the same time that the steam cock is made to shut off further ingress for steam; this cold water condenses the steam in the cylinder, which falls to the bottom as water, and is discharged by the air-pump; and thus forms a vacuum under the piston, which is, in consequence, forced down again by the weight of atmospheric air; and as it decends, the pump rod, fitted to the opposite end of the sway beam, rises, and lifts the water from below. A 40 inch cylinder will be acted on with a force of 24,000lbs upon the piston, and of course will lift that weight at each stroke. Such a cylinder, with a 7 feet stroke, and pump of 10 inch diameter, is calculated to rise about 300 hogsheads of water 100 yards deep, in an hour.

ECCENTRIC ROD C



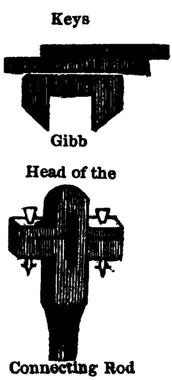
Is fitted with a ring round the intermediate shaft and comes down from it to the traverse shaft, forming an angle of about 2½ degrees. At its lower extremity there is a shoulder, or notch, for for the reception of the traverse shaft (which works the slide valve and governs the steam) when to be put in "track," that is, when

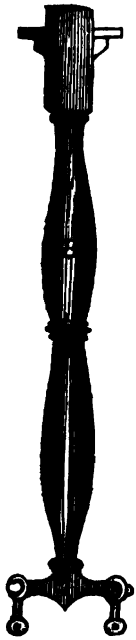
ready for operation. The eccentric ring is fixed round the intermediate shaft N, with two clutches, or catches, on the shaft, as checks. To this the rod is attached (by a brass ring round the wheel) for working the D slide valve, whereby the admission of steam into the cylinders is effected, at the top or bottom of the piston. The pin on which the ring revolves, is not in the centre, but fitted to ⅛ from the outer edge, so as to cause the "excentric" movement; if in the centre, it would be circular. A counter weight is appended.

CONNECTING ROD B

Is attached at its upper end to the bearings of the intermediate and crank shaft, connected by a pin;* and when in action, has an angular motion. The lower end is

* Maudslay's Engines are fitted with a screw crank pin in the paddlecrank; taking out which pin, enables us to work either one or both wheels, at our option; and is therefore preferable to Bolton and Watt's plan of Gibb and Key. This latter, however, is better adapted for *expedition*, when necessary to disconnect in cases of sudden expediency; such as, accidents occurring at a time the vessel may be in a position of danger, or intricacy, from rocks, sand banks, narrow waters, &c. when it may be necessary to work the vessel into safety by using the effective engine only. By this latter plan, we can disconnect in about three minutes.





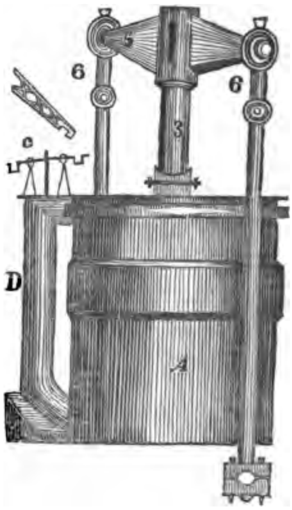
fitted into the fork head, (7) a strong bar, or plate of iron, which stretches across from one working beam, or side lever, to the other, (of the same engine) and connects them together. The two connecting rods, (one for each engine) work at opposite angles with each other, and cause the cranks to pass over the centre, or line of perpendicular, with facility. They effect in the marine engine, what the fly wheel does in the land engine, and cause the rotatory motion of the paddle-wheels, by forcing the cranks round.

In case of any accident happening to either of the engines, of a nature to prevent working that engine, this rod must be disconnected from the crank and working beams, so that one engine alone shall act, and turn both wheels. The difficulty however, which accrues in this case, is to get the cranks over the centre, and requires great attention.

SIDE RODS (6)

Lead from the lower end of the working beams, upwards, and alongside of the cylinders, parrallel with the

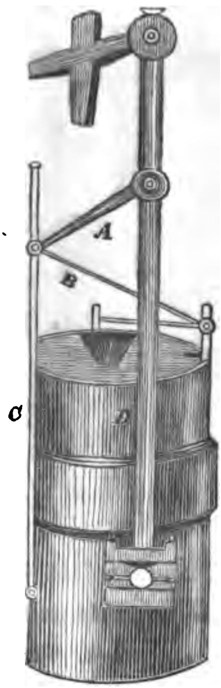
piston rod (3) or air-pump rod, for working the piston or air-pump; these side rods and the piston (or air pump) rod are connected together at the top by a cross-head (5).



The side rods for working the air-pump bucket, are attached to the working beam also, but about one third of its length from the end. The sway beams, (or working beams, as they are likewise called) are connected at one end by the fork-head, at the other by the side rods and in the centre, with the main centre of the engines, which is on the top of the condenser. (In the annexed sketch, *c* represents the way shaft over the D slide, which is worked by the eccentric rod.

RADIUS RODS AND WAY SHAFT.

The radius rods are bars, or arms, for parallel motion, and are secondary beams attached to the parallel motion rod; they lead from one third, upwards, of the side rods (see the annexed diagrams) to the way shaft, over the



A B Radius bars
C Parallel motion rod
D Side rod

D slide, and keep the piston rod in a perpendicular position, during its motion upwards and downwards.

The way shaft passes transversely over the D slide, and is fitted with a kind of crank called the driving pin, over which the notch of the eccentric rod is placed, when in track for supplying steam to the cylinders, by working the slide valve.—See the foregoing diagram (C). N.B. The way shaft is sometimes called the traverse shaft.

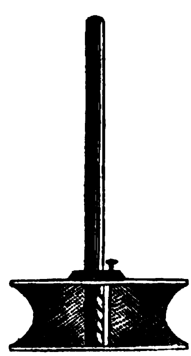
MOTION ROD, AND PARALLEL MOTION ROD.

The motion rods, or radius bars, are the same. The parallel motion rods are fixed at the lower end, to the working beams, and are the same as the motion rods; they are a continuation of simple bars, whereby the parallelism, or vertical right lined motion of the piston rod is insured, during its passage upwards and downwards.

LUBRICATORS.

Small funnels, stuffed with hemp or tow, and filled with oil; these are dispersed about the sundry parts of the engine which are liable to friction, such as the bearings, cranks, &c. Care should be taken to see them well attended, and oil added from time to time. Those of the bearings and plomer blocks demand especial attention; as, in case of their being screwed too tight, the friction may cause the head of the connecting rod to become nearly red hot. The quantity of oil however, should be proportioned to the probable time the engines will be at work; if a few hours only, not more than half filled, otherwise great waste will ensue. Some of the lubricators are fitted with a screw cover, which contributes greatly to a saving of oil.

PISTON AND PISTON ROD.



The piston and its rod work in the cylinder; and as the effective power of steam is brought into action through their agency, it behoves us to be especially careful that the engineer looks well to the packing of the piston, and to the secure bolting of the rod, which should pass through the piston; and not to trust to the slight manner in

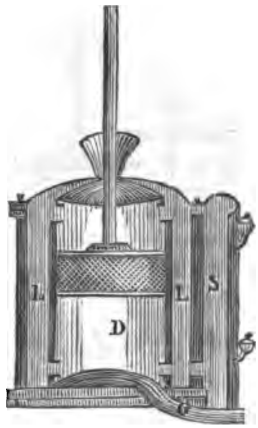
which it is frequently fitted, as accidents of the most serious description must ensue, should it get loose.

The metallic pistons of Barton, Maudsley, &c., are now so greatly improved as to merit general adoption;—they obviate the necessity of packing, the piston being fitted with a metallic ring, instead of a plating of cinnet; which ring is kept distended by strong springs, and fits itself compactly to the interior of the cylinder—they are well adapted for long voyages, as they save labour, as well as time. The common packing however, is a plaiting of hemp into cinnet, and inserted into the grove which encircles the piston; and has for its object the rendering the piston so perfectly tight, that no steam can pass between it, and the sides of the cylinder; which, if it did, would diminish the effect of the steam power, in the proportion of the quantity so lost; and at same time burn the packing.

CYLINDERS

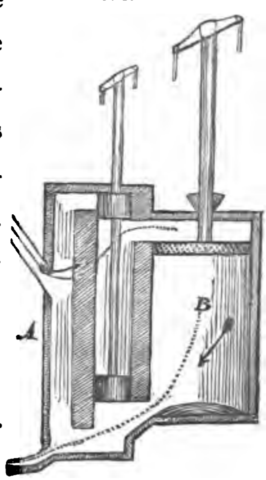
Are the receptacles for the steam, when the machinery is at work; and are supplied from the steam chest, or reservoir, placed over the boilers, by means of the steam pipe, and throttle valves; and as the whole force of the steam is here concentrated, they are made of a

solidity and thickness adequate to resist the degree of steam power, at which the engines are to be worked. Whilst the engines are in operation, the cylinders must be kept as hot as the steam which enters them; to effect which they are made double: the inner, or working cylinder, has the piston within it; the outer is merely a case which encircles the inner one, and is termed the "Steam Jacket." This latter serves as a coating, and the steam is made to circulate between the two, and thereby to keep up the required temperature; the coldness of the atmospheric air is thus excluded, by this intervention of steam, within the jacket. By this contrivance an otherwise waste of fuel is avoided; as the steam within the working cylinders is secured from premature condensation; and the saving of fuel is in proportion to the saving of steam. The more ef-



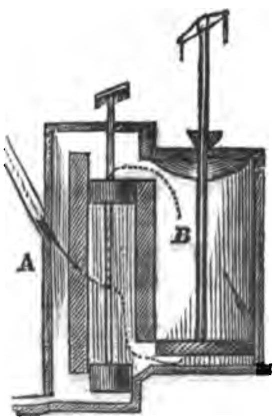
D Section of cylinder
L Steam jacket
G Eduction pipe
S Slide jacket

No. 1.



Open for Steam at Top.
A Slide Jacket B Escapement

No. 2.



Open for Steam at Bottom.

A Slide Jacket

B Escapement

fectually to prevent the cylinders from being chilled, when condensing engines are used, the condenser, upon which it is dependent for the formation of a vacuum, is made distinct and separate from the cylinder, having a communication, however, between the two, by means of a pipe, or passage, called the "Eduction pipe," for the escape of steam from the cylinder, after it has completed the stroke, into the condenser. For though the action of the one is in unison with the other, yet the cylinder requires to be kept hot; whilst, on the contrary, the condenser must be as cold as possible. At the top and bottom of the cylinder are apertures, with valves for the admission of steam, as the valves slide upwards or downwards within the slide jacket. The cylinder covers are furnished with grease-cups, stuffing-boxes, and escape-valves.

That Engineers are more or less limited, as to whether they shall place the cylinders forward or aft, in the vessels, I am aware, as it depends upon the position of the paddle-wheels; but were the Shipbuilder and Engineer, who furnishes the machinery, to consult together prior to the

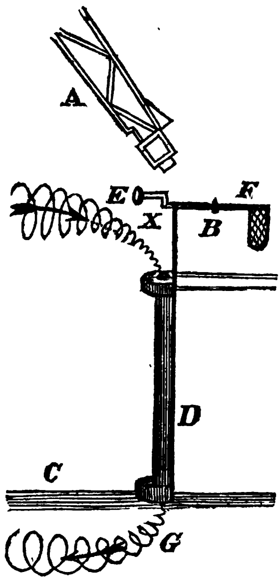
construction of the vessel, satisfactory arrangements might be made on this point; for it is evidently a mistaken principle to place the cylinders *forward* instead of *aft*; first, on account of their weight, which exceeds that of the frame-work of the engine, and, consequently, tends to bring the vessel down by the head; and, secondly, by placing them forward, the steam-pipe must necessarily be of considerable length: the effect of which is, that as the steam has all that distance to pass through the atmospheric air, by which the pipe is surrounded, so it must of necessity be condensed, more or less, in proportion to that distance, ere it gets into the cylinder.

NOTE.—To preserve the cylinder covers from the effects of sea-water or rain, mix together unslacked lime and tallow, and lay this over them on proceeding to sea; the lime will absorb the wet, and prevent rust.

THE D SLIDE, OR SLIDE VALVE

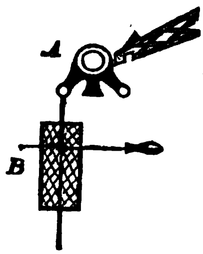
Is so named from its form: the flat surface is made to fit steam tight upon the inside of the box in which it works; and the D or semicular part, is packed at the top and bottom, similar to the piston. This valve is worked by the eccentric rod, coming down from the crank shaft; and communicating with the traverse

shaft, by its notch. The projecting parts to the left of the perpendicular line of the D, serve as stops, to close the apertures top and bottom of the *cylinder,* through which the steam, after circulating through the jacket of the slide valve, passes into the cylinder. The slide is made to move, steam tight, in the passage or jacket, upwards and downwards. If the upper aperture of the cylinder be open, (as in No. 1 of the preceding diagram) the steam communication is *cut off from admission into* the cylinder through the *lower* one; though the lower aperture is open for the *escape from* the cylinder of the *exhausted* steam below the piston which on the lifting of the air-pump and foot-valve of the condenser, rushes from thence into the condenser, meets the cold injection, is converted into water, and leaves a vacuum under the piston, where the *steam just previously was.* At the same time, fresh steam is admitted through the *upper* opening of the cylinder at the *top* of the piston, and as there is no longer any resistance, forces it down-



A Eccentric rod
B Pivot
C Deck
D Slide
E Traverse shaft
F Counter weight
G Eduction pipe

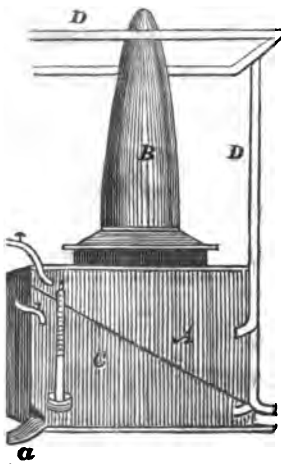
wards. By the time it has got to the bottom of the cylinder, the slide valves change their position (by the action of the eccentric rod on the traverse shaft, which works the D slide up and down) and the *lower* aperture of the cylinder opens for the *admission* of steam into the cylinder, *under* the piston; and the upper one, though now closed to *admission*, is nevertheless open for the passage of the *exhausted* steam from above the piston, *out of* the cylinder into the jacket of the slide valve X and thence to the condenser, where it, in turn, becomes water, and leaves a vacuum above the piston, &c. &c.—This exhausted steam *from the top*, passes down through the hollow (which in the diagram annexed, is *black)* within the slide, and by means of the eduction pipe, or outlet, into the condenser. The slide has a counterpoise (of the same weight with the slide, when the packing is off) and the counterpoise is a block of iron. The slides are sometimes made of brass, as on board H. M. S. V. Blazer.



A Traverse shaft
B Starting lever and counterpoise.

CONDENSER AND EDUCTION PIPE.

This is the cistern which communicates with the cylinder, as already described and is fitted to the engine for



Exterior View.

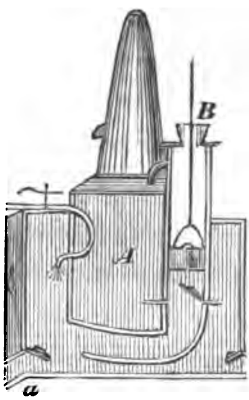
A Hotwell
B Air cone
C Condenser
D Feed pipes

the purpose of forming the vacuum, whereby the action and reaction, otherwise the ascent and descent of the piston, which works within the cylinder, is brought about. This movement is effected by the alternate increase and decrease of the temperature of steam; for its elasticity is derived from the quantity of heat which it contains, and its force increases and decreases with that quantity of heat. The higher the temperature of the steam employed, and the quicker it can be condensed, the greater the perfection attained.

By the separation of the two, (the cylinder and the condenser) the operative steam within the cylinder is kept uniformly at the proper heat, at the very time that that to be discharged is being condensed, or brought down to the temperature of the atmosphere, preparatory to being drawn off by the air-pump, and forced into the hot water cistern, and from thence back into the boilers, or through the ship's side. For the temperature being thus reduced, steam reassumes the state of water; thereby leaving the

space which in its expanded state of vapour, it had occupied in the cylinder, again void.

Between the cylinder and condenser the communication is kept up by means of a pipe, called the "Eduction pipe," (*a*) or outlet for the passage of exhausted steam from the cylinder into the condenser, to meet the cold water from the "Injection pipe;" after forcing open the foot valve* by its elastic force, it comes in contact with the cold water, and instantly becomes reduced to its



Interior View.
A Hot Well
B Pump

original state of water, and causes the *vacuum* in the space it occupied within the cylinder, whereby a fresh supply of steam can immediately rush into the cylinder through whichever aperture is open to it, top or bottom. The air-pump and condenser work in unison also, and the former discharges the air, as well as the water, which enters the cylinder, whether with the condensing water or otherwise. The condenser is furnished with a constant

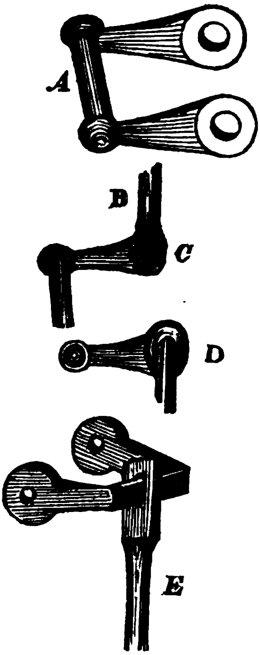
* If *too much* injection be admitted, it will be discovered by the "banging" of the foot valves; if *too little*, by the engines "blowing through." No inconvenience need be apprehended from either, as a few seconds will suffice to remedy the error. About 5 gallons to 7 is the quantity of cold water admitted at each stroke into the condensor.

supply of cold water (on board ship) from the vessel's side, by the injection pipe, or from a pump, if on shore. Over the condenser is fixed the "Hotwater cistern," for the reception of the water from the condenser, forced up by the air-pump, and from thence, whilst still warm, returned to the boiler through the feed pipes, to be again converted into steam. These are attached to *condensing* engines only. On rail-roads, or where there is a scarcity of water, high pressure engines are had recourse to, and the exhausted steam is discharged into the open air, consequently becomes a total loss. The injection pipe leads through the ship's side below the water line, and is covered over with copper, punctured with holes; or, which is better, a small grating of about half inch apertures; for if the holes are too fine, they sometimes become choaked with seaweed, or grass, and the injection of course fails. N.B. The condenser is usually of rather greater capacity than the air-pump; because the more space for vacuum the quicker is steam condensed.

CRANK SHAFT AND ROTATORY MOTION.

The crank shaft passes through the head of the connecting rod, which revolves round it, at the same time that it forces the crank round, to impart the rotatory motion to the wheels. They are placed at right angles

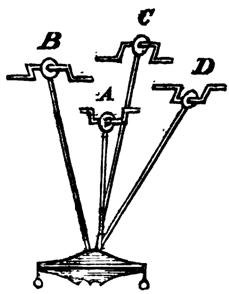
with each other, and are attached to the paddle shaft, and the intermediate shaft, being between the two, each on its own side, starboard or larboard.



A Bolton and Watt's Crank
B Paddle shaft
C Maudslay's Disconnected
D Intermediate shaft
E Connected

The steam having been admitted into the cylinder, and the vacuum formed at top or bottom, the piston is set in motion: the rod of which being connected by its cross-head to two side rods (see Frontispiece) working parallel with it, on each side, and fitted to the ends of the working beam, by pivots, presses that end down (or draws it up, according as the piston is falling or rising), and of course, causes an opposite movement to the *connecting* rod, the *lower* end of which is fitted to the further end (from the cylinder) of the working beam, by its fork-head, which connects the two beams (of the same engine) together, and also moves upon pivots. The working beams are balanced in the centre on pivots likewise. The heads, or working ends of the *connecting rods* are attached to the *cranks* which link together the inter-

mediate and the paddle shafts (each on their own side, for the starboard and larboard engines); and the cranks themselves are placed at right angles with each other, or 90°, whereby they alternately force each other round, as in turn, they approach the centre, or line of perpendicular; giving a corresponding rotatory motion to the *wheels*, which are affixed to the paddle shafts outside the vessel.

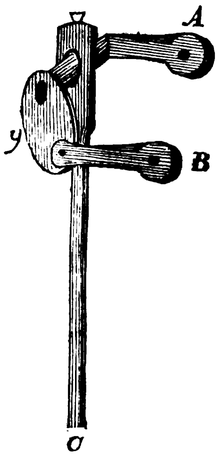


A Centre
B Rising
C Past the Centre
D Falling

Thus, as the ends of the working beams, to which the *side rods* are connected, descend, the connecting rods, at the opposite end of the beams, rise, and force the cranks upwards, the shaft, or spindle of which, revolves within the head of the connecting rod, and enables the latter to play with a circular motion, as it passes through the several positions. This effect will be rendered familiar by reference to the spindle of a Knife-grinder's wheel; the cranks of which are placed in the same way, that is, at right angles with each other.

PADDLE AND INTERMEDIATE SHAFTS.

The paddle shaft passes from its crank as far outward



A Paddle shaft
B Intermediate shaft
C Connecting Rod

as the outside of the paddle-box, and serves to support, as well as to turn, the wheels. The intermediate shaft drives the paddle shaft; and has a corresponding crank shaft affixed to it. The drag link is between the two.

THE DRAG LINK

Connects together the crank shaft and the connecting rod; the crank shaft revolves within the head of the connecting rod. The drag link is shewn at *y*.

VACUUM.

The vacuum is formed by the condensation of steam; that is, by the abstraction of its surplus heat. Steam we will say, occupies the space which otherwise would be filled with air; but as air could not be so readily dissipated as steam, so by the application of steam, and the introduction of a jet of cold water upon it, when required that it should be dissipated, a vacuum is formed in the space which it just before occupied; that is, the space is made vacant.

Hot steam is very elastic; and when cooled by contact with cold water, it parts with the caloric which maintained it in the form of vapour, and its elasticity is immediately destroyed; whence it is again reduced to water; which, falling to the bottom of the vessel containing it (the condenser) is drawn off by the air-pump, through the foot valve of the condenser, (placed at an angle of about 45°) forced back into the boiler, or, if too redundant, through the vessel's side into the sea, and leaves a cavity within the cylinder, which is almost a perfect vacuum. There being then no longer a resisting force, in consequence of this cavity, say *under* the piston, fresh steam, as it rushes into the cavity, drives before it any other body (in this case the piston) which will yield to its pressure, and it is thus forced upwards—and vice versa.

But as a vacuum, if taking place within the *boilers*, (in contra distinction to that required in the cylinders) would tend to their being crushed by the weight of atmospheric air, it is necessary that the boilers should be fitted with "reverse valves."—N.B. The quantity of injection water received in the condenser is about 5 gallons each stroke.

REVERSE, OR VACUUM VALVES

For the prevention of a vacuum within the boilers.—As

the safety valves open outwardly to give egress to steam, so the reverse valves open inwardly, for the admission of atmospheric air. Suppose a vessel (boiler after the water has been blown out) to be filled with steam; as the boiler cools this steam will become condensed, fall to the bottom as water, and leave a vacuum, in the space over it which, as *vapour*, it previously occupied; and were a pipe made to communicate from the boiler to a cistern of water; the pipe being fitted with a stop cock, on opening the cock, the boiler would be soon filled with water from the cistern; being forced into it by the pressure of atmospheric air; but in the absence of such pipe, the same degree of atmospheric pressure would act upon the external surface of the boiler, and probably crush it in. To prevent this effect of vacuum, within the boilers, they should be fitted with a "reverse valve," which will open when blowing off the water, and admit the air to rush in, in the same ratio as the water goes out, and gradually fill up the space vacated by both water and steam, on the same principle as would the water from the cistern; and become a sustaining cause.

INJECTION AND BILGE-PIPES, AND PUMPS.

As steam from the cylinder would soon heat the water in the condenser, unless it be frequently changed, a con-

stant supply of cold water is made to run into the latter from outside of the vessel, by means of a pipe, called the "injection pipe;" which injection pipe furnishes the supply required for condensation; it is fitted with a cock whereby to regulate* the supply, as also to shut off the communication with the sea, when necessary.

The *hot* water is drawn off by the air-pump, and forced up into the "hot-water cistern," and from thence into the boiler.

The bilge-pipes lead up through the ship's side, and being worked by a plunger, or pump, attached to the working beam, forces the bilge water through the vessel's side. It is generally found necessary to furnish this pipe with an air-vessel, to induce a free vent of water.

In addition to this bilge-pipe, all steam vessels should be furnished with extra pipes, which *on occasions* may be made to supply injection for condensing the steam, instead of the usual injection pipe. These extra pipes are proposed to be worked by the air-pumps, and not by the bilge-pumps, and to be fitted to the injection pipes close to the condenser, and communicate with the bilge; they are in fact additional bilge-pipes. The vast importance of

* Should any thing go wrong with the engine, the first thing is to shut off the injection and throttle valves.

which these pipes are susceptible, in the few vessels in which they are fitted, does not appear as yet to have attracted the attention of Engineers generally, else we should have had more minuteness shewn in the proportioning of them to the injection pipes; which is a matter of the utmost import, and is dependent on the locality of position. Neither would any steam-vessel be without them were their value properly appreciated.

By the concurrent testimony of the persons examined touching the loss of the *Rothsay Castle, Steamer,* it appeared that that catastrophe was attributable to an accumulation of water in her Engine-room, arising from a leak. Had she been protected by these proposed *additional* bilge-pipes, so calamitous a fate would have been avoided, as, if properly apportioned to the injection pipes, that is, of sufficient diameter to admit of supplying the injection water in *equal proportion* to the injection pipe itself, (which in such case would be shut off) whilst at the same time, by aid of the air-pump, the redundant water is drawn off, and discharged out of the vessel in the same way that the condensed water is disposed of; a vessel thus fitted, although she may spring a leak, may likewise be kept free by her own engines.

An Engineer, however, must on no account *unnecessarily* have recourse to these extra bilge-pipes. On the

contrary, he is not to do so *except in cases of absolute necessity;* they are mere preventives. But to render such extra bilge-pipes efficacious, care must be taken to proportion both the bilge and the injection pipes to their *local situations* in the vessel, in such manner as will insure a supply for condensation from the bilge, as already noticed. Without this precaution, the attempt will be productive of mischief if had recourse to in the hour of peril; as, should the injection fail, the engines must necessarily stop for want of a proper vacuum; and before the sea cocks could be opened time must be lost; and, during that stagnation, the accumulation of water must necessarily increase.

In the few Steam Vessels which are fitted with these additional bilge-pipes, this precaution has been disregarded, and both they and the injection pipes are, I may say, invariably of the same diameter. This requires to be amended; and by way of illustration, in one Steamer so fitted, the sea pipe (the injection pipe is called likewise the *sea pipe*) is eight feet below the surface of the sea. Now admit the barometer on the condenser to stand at 26°; and take the fact, that 30 inches of mercury are equal to 33 feet of water,—this, by the rule of proportion, will give for the 26° of mercury 28 feet of water; to which add the distance of the sea pipe from the surface of the sea, 8 feet, we then have 36 feet for the head of the water above the

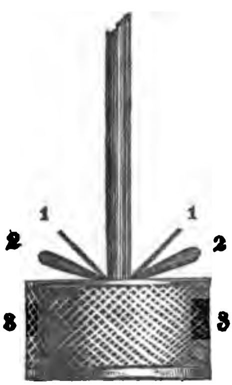
sea pipe. It is also known, from experiments, that the velocity of water flowing out of an aperture, is as the square root of the height of the head of the water; which for 36 feet will give 6.

Now if we use the bilge-pipe, which (in the same vessel) is nine feet in length, the water must be drawn nine feet by the vacuum in the condenser; subtract this from the admitted vacuum (26°) or 28 feet of water, and we have 19 as the remainder, the square root of which will be about 4.750; which gives, as the proportions for the area of the bilge-pipes, four inches for every six of the injection pipes. Thus the error is apparent; and instead of having the bilge-pipe, four inches area to six of the sea pipe, the reverse should be the proportion; and the bilge-pipe should furnish six gallons of water to four of the sea pipe.

But the duly proportioning of the various pipes with which the Engines are furnished requires considerable amendment. The blow-off pipe, under the boiler, especially; in that portion of it, which receives the joint contributions of the small branch pipes immediately connected with each particular boiler, it should be of a diameter adequate to contain the whole mass of water which those smaller pipes collectively send forth; else, when blowing off the whole set of boilers at the same

time, (a practice highly recommendable *when arrived in Port after a long voyage*) this accumulation of waters, when meeting together, are apt to burst the main pipe; and if it does not, it is solely owing to the prudent caution of the Engineer in proportioning the steam from each boiler, instead of opening the valves altogether. In this latter case half the effect intended by the operation of "blowing off" is lost; for it is clear that the stronger the gush of water from the boilers, the more certain it is of carrying away the sediment collected within them.

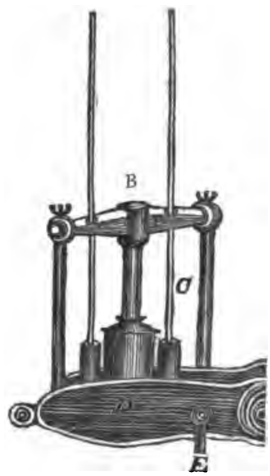
FEED AND AIR-PUMPS AND BUCKET.



1 Checks
2 Clacks
3 Air-pump Bucket

Air being unavoidably introduced into the cylinders by the injection water, leakage, &c., the air-pump becomes a necessary appendage, to free them from both air and steam water. It is worked by the sway, or working beams, to which it is attached by two side rods (similar to, but smaller than, those of the piston rods) at the bottom, and fitted at top with a cross-head. When to be put in track a pin is thrust in close to the cross-head, just above it, which

fixes the rod of the air-pump, and the movement of the sway-beams works it. One of the side rods is, properly speaking, the feed-pump rod, and fixed to the cross-head.



B Air-pump rod
C Feed-pump
D Working beam
E Bilge-pump

FEED-PUMPS AND PIPES.

Each engine has a feed-pump fitted alongside its air-pump; and it is worked by the cross-head of the air-pump; the pump-rod being fixed by a screw to the cross-head. This pump forces the feed water up into the boilers through the feed-pipe;* and replenishes them with water in proportion to that diminished by conversion into steam; or expelled by the operation of "blowing off." If the fires are rendered too fierce, and the steam within the boilers raised too high in consequence, the operation is reversed, and the water *from the boilers* is sometimes forced by steam pressure into the feed-pipes; wherefore, attention

* A small branch pipe of the same diameter, may be attached to the feed-pipe, and leading upwards on deck, may be made to supply warm water for washing decks, clothes, &c.; the hose being screwed on as usual, will convey it to all parts of the vessel.

must be paid to judicious firing, in order to prevent this; as also to the guages, to prevent accidents from a too great diminution of water in the boilers. See articles "Blow-off Pipe," and "Safety Pipe."

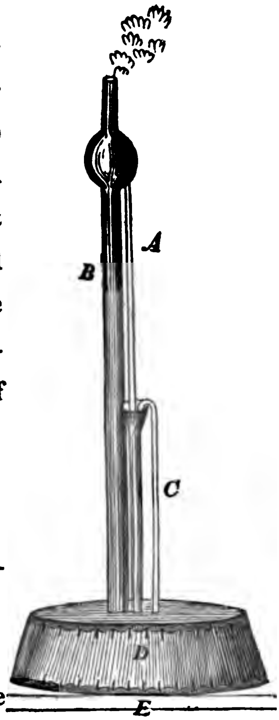
WASTE WATER PIPE.

This pipe is connected with the feed-pipe; and serves to convey away whatever superabundance of water the boilers or the feed-pipe may be charged with, which it discharges through the vessel's side. The waste steam pipe, and the waste water pipe, usually lead through the opposite sides of the ship.

WASTE STEAM PIPE

Is a small pipe above deck in front of the funnel, and through which the surplus steam from the steam chest, passes off through the safety valve. It is, or ought to be, fitted with a bulb, about one third down from the top, in order that the steam may be condensed within it, during its progress upwards, before it can disperse itself into the open air. A smaller pipe leads down from the bulb, and passes out at the ship's side, for the purpose of conveying away this condensed steam. Otherwise, should the steam

issue out at the top, instead of being thus arrested by condensation through the medium of atmospheric air, acting on the bulb, the aqueous particles would mingle with the smoke and soot from the stack, or chimney, and falling on the deck, adhere like paint, to whatsoever it lights upon, to the great detriment of clothes, &c.



A Condensed steam pipe
B Waste steam pipe
C Waste water pipe
D Casing of the steam chest
E Deck

BAROMETER AND VACUUM GUAGE.

The barometer is affixed to the condenser, and indicates the degree of vacuum, consequently the amount of pressure on the piston within the cylinder. It consists of a common barometer tube, with an index card, or graduated scale; and a small tube from the condenser communicates with it, whereby the mercury is made to rise or fall as the condensation is complete, or the contrary. This guage shews the power of atmospheric pressure on the piston; and it is a true and infallible indicator of the working condition of the engine,

and serves to detect any leakage from bad joints or otherwise; as also whether the stuffing-boxes are tight. When the condenser and air-pump are both in order, the mercury will ascend to 27 or 28°, or even higher; and this will be shewn on the graduated scale; then if we allow one pound pressure for every *two* inches of the rise of mercury, we are assured that, if at 28°, we have a vacuum of 14lbs on the square inch. Then to find the power (that is, the actual pressure) of the engine, add to this 14lbs, the pressure *above the atmosphere*, at which the steam enters the cylinder (see "Thermometer or Steam Guage"). Thus, if a low-pressure engine, and steam of 3lbs per square inch, it will give 17lbs* as the effective pressure; but as nearly half the power is lost by friction of the various parts of the engine, this must be deducted, (on an average about 8lbs) which makes the actual pressure at which the engine is working, 8 or 9lbs per square inch. If using steam expansively, and shut off at, say, half stroke; if admitted at 15lbs per square inch pressure, and vacuum 14lbs, give 29 as effective pressure; deduct friction, one half, makes about 14lbs the amount of actual power of the engine.

* Vacuum 28 degrees or 14lbs.

Steam	3
	17
Deduct friction	8
Working power	9

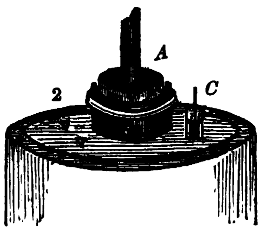
N.B. To find the horse power of an engine, and to increase the horse power of the same engine, see article "Horse Power."

THERMOMETER OR STEAM GUAGE

Is a bent tube attached to the steam jacket of the cylinder; it exhibits the height, or temperature, at which the steam is working. If the level of the mercury in *b c* be above that in *a b* the pressure of *steam* exceeds that of the *atmosphere* by that much, shewn on the graduated scale, in the proportion of 1℔ for every 2 inches rise of mercury. If the mercury be equal, or on a level, in both legs of the bent tube, the steam pressure and the atmospheric pressure are equal; if however the mercury in *b c* be lower than that in *a b* the atmospheric pressure predominates over that of the steam, in the proportion indicated by the guage. By attention to this guage the fires may be duly regulated, both as to the proper maintenance of steam, and the economic supply of fuel. It likewise serves as a check on the safety valve, by shewing the force of steam, when from accident the valve may not lift, and there is no safety pipe fitted to the boilers.

STUFFING-BOXES AND GLANDS, WITH ES-CAPE VALVE AND GREASE CUPS.

The glands fit over the stuffing-boxes which contain packing round the piston, and air-pump rods, &c., to prevent the passage of air or steam. It is here the piston rods pass into the cylinders. They are kept filled with melted tallow; which, flowing through the cylinder cover, spreads over the piston, and keeps it steam tight. The escape valve discharges any surplus steam.



A Glands B Stuffing Box
C Escape Valve
2 Grease Cups

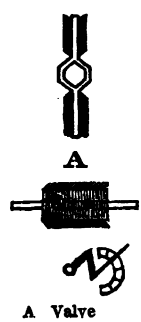
GREASE CUPS.

Those of the cylinder covers must always be kept filled with tallow for working the piston; those of the bearings, or shaft crank, are supplied with oil; the latter by means of funnels and tubes, called lubricators, furnished with hemp or cotton, through which the oil, dripping gradually, communicates with the bolts of the bearings, and causes them to work easy. In lubricating the engines, it is found that the harder the lubricating substance, the less likely are the bearings to become overheated. Hence, melted tallow is preferable to oil; but

this may be improved by mixing in with it soft soap, which causes a *froth* about the glands, and proves a barrier to the passage of air. And where oil must be used instead of tallow, sulphur, in an impalpable powder, has the effect of rendering it substantial, and thence keeping the parts, to which it is applied, cool. Care must be taken that there be no grit; which, from what motive I know not, is almost constantly the case with the tallow sent on board Her Majesty's Steamers, it being found mixed with considerable quantities of lime. And for which reason it is recommendable never to use it cold, (unless previously clarified) but melt it, and let the sediment fall to the bottom; for this purpose a tallow box may be attached to the top of the steam pipe, close to the boiler, having a tube leading from it into the glands and stuffing-box.

THROTTLE VALVE.

This valve is fitted close to the D slide, and admits the steam into the engine, and regulates the motion of the piston, whereby a fast, easy, or slow motion is imparted to the wheels, by opening, or closing the valve, consequently admitting more or less steam. It is worked in unison with the injection cock: if to ease the vessel's velocity, both



are partially closed; if to stop her, the throttle valve and injection cock are shut off altogether, and the eccentric rod pushed out of gear from the traverse, or way, shaft. The throttle valve is bevelled off on each side, and has a spindle passing through, by which it is opened, or shut off. Valves, in fact, serve the purposes of cocks.

THE NOZZLES AND JACKET OF THE SLIDE VALVES.

The nozzles are the top and bottom of the cylinder for the admission of the D slide. The jacket of the slide is that where the steam enters the cylinder; but its place is supplied by the "Expansive gear" when steam is used expansively. The diameters of the valves of the nozzles are about one-fifth that of the cylinders.

THE JACKET COCK

Is fixed to the under side of the cylinder, and should always be kept more or less open when the engines are at work, in order to draw off the water from them, as the steam within the jackets becomes condensed. A cock properly fitted to the jacket of a 40 inch cylinder will yield about two and a half gallons, of pure fresh water,

per hour. H. M. Steam Vessel, African, by an expedient of this nature, dispensed with eight water tanks from her hold; and on board H. M. Steam Vessel, Comet, this water was constantly used,* on all occasions when hot water was required.

PLOMER BLOCKS

Are clamps, or brasses, which confine the paddle shafts, &c. to the bearings, similar to the cap squares of gun carriages which confine the trunnions down.

TRAP HATCHES OVER THE COAL BOXES.

Although we have as yet had no serious occasion to deplore the remarkable remissness of precaution against the calamity of conflagration on board of Steamers, which is so universal as to be, I believe, without an exception, notwithstanding that we see, or rather hear, of the frequency with which the coals on board of them ignite, and burst into flame, it would be, at the least, prudent to pro-

* A tank might be fitted under the cock, and a small force pump, worked by the engine, would supply the deck tanks for daily consumption, with either warm or cold water, as required. A similar appendage attached to the "blow through valve" would intercept oil, grease, dirty water, &c., from the cylinder, without its getting into the bilge.

vide such remedy as shall effectually allay alarm on such occasions, and satisfy the minds of passengers, or other persons inconversant with the resources to which, under ordinary circumstances, recourse can be had for checking the progress of fire,* through the medium of the multiplicity of pumps, pipes, hoses, &c., on board.

To this end, I beg to suggest the propriety of cutting hatches over the coal boxes on each gangway; these hatches to be about four or five planks wide, and from six to eight feet in length; fitted with ring bolts for the insertion of crowbars, and caulked in (if comings be objected to), so that in the event of the coals taking fire within the boxes (which they frequently do on board sea-going, or long-voyage, steamers, owing to the unavoidable accumulation of damp, or wet, at the bottom; and which causes them to sweat, thence to heat, and eventually to burst into flame; and when near the furnaces, the upper stratum of those coals being heated artificially, and perfectly dry, combustion is likely to spread rapidly), the application of the caulker's screaving iron to the seams, will soon free them from the oakum, &c., and they may

* All vegetable matter when gathered into a heap, if possessing no more water than just sufficient to excite fermentation, will quickly evolve heat, this heat increases as the particles coalesce more closely, (and is greatest near the centre) and at length takes fire. Whether this arises from the absorption of oxygen, or that the caloric of the vegetable is disengaged, I am unable to say.

be lifted out; but comings would be preferable, and there would be no occasion for caulking down, as neither rain nor sea water would pass down.

By this means, we shall not only have an opportunity of getting at, but if necessary, "getting out" the coals, in order to suppress the fire; neither of which, is it possible, under present circumstances, to effect. And, furthermore, we should thus be afforded a facility for *stowing* coals as they are received on board, instead of the promiscuous "shoveling down" as at present; and, consequently, by such *packing*, be enabled to take a considerably larger quantity in the same space, than such shoveling down heretofore admitted of.

Among numerous instances, I may adduce that of H. M. S. V. Carron, on board which, the carpenter was once under the necessity of cutting scuttles, or rather of "ripping up the decks" over the coal boxes, from the ignition of her coals spontaneously. A more recent, and very similar case occurred on board the Sir Francis Drake, between Guernsey and Jersey; also H. M. S. V. Salamander, &c. But it should be recollected, that whilst scuttles are being cut, the fire is burning, and danger on the increase; and this spontaneous ignition of coals, a somewhat common occurrence.

Memo. Since the above was written, H. M. S. V. Meteor, arrived from the West Indies, and the plan proposed had been judiciously adopted by her Commander, whilst at Jamaica; thus fully corroborating the justness of the foregoing remarks, that vessel having likewise been on fire from the same causes.

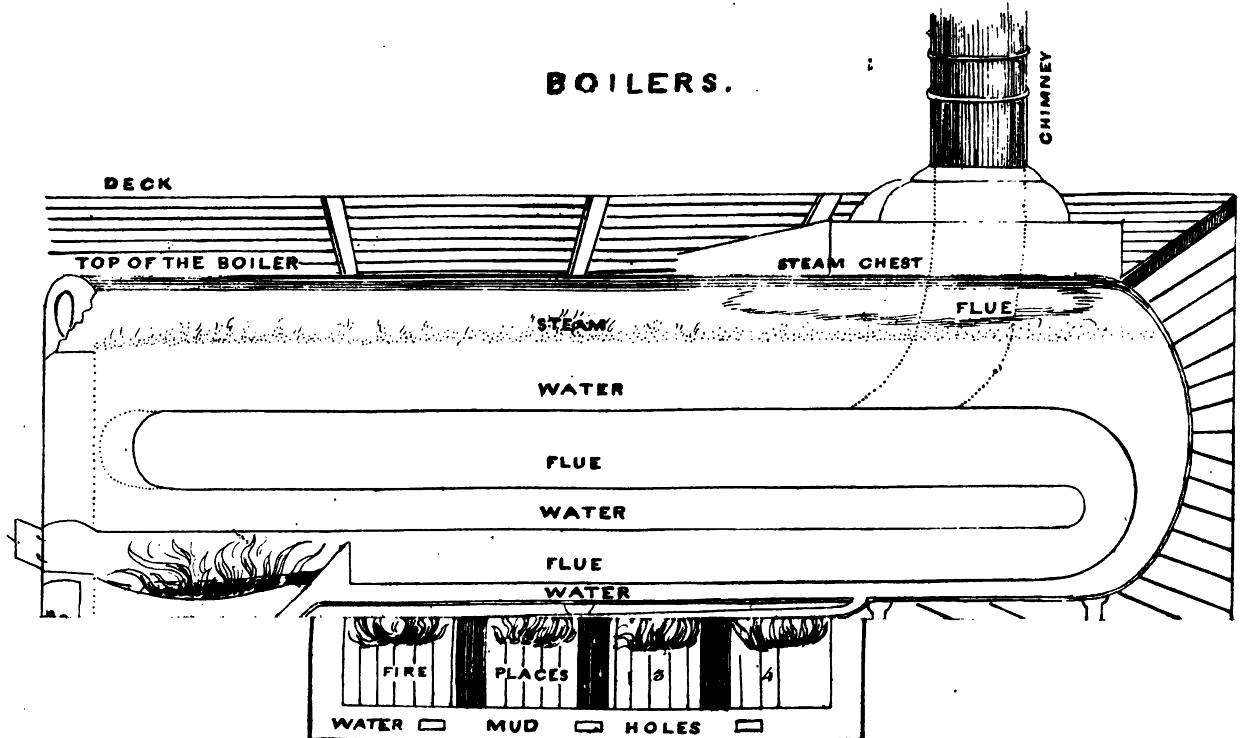
TRAP HATCHES OVER THE PISTON RODS.

The very great difficulty to which we are subjected in getting in, or out, the pistons, renders it a subject of serious consideration whether it is not advisable to have hatches fitted over the cylinders. Shifting a piston rod at sea is a matter of importance; I, myself, have felt this inconvenience, off the Rock of Lisbon, having had one of the sway beams broken, which bent the side and piston rods and rendered them unserviceable. Other causes may arise for rendering it expedient to get the pistons out whilst at sea; and, as Steamers are now fitted, this is an operation of considerable difficulty and very considerable loss of time.

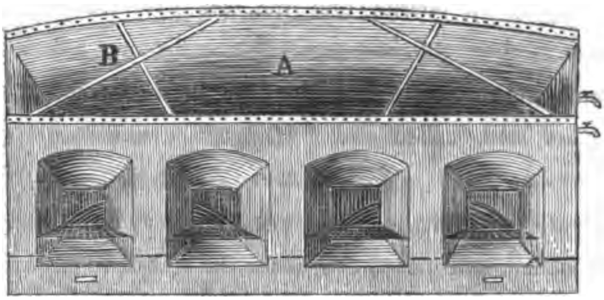
BOILERS

Are of various forms, both externally and internally,

BOILERS.



INTERIOR VIEW OF A SQUARE BOILER (THE SET.)



Front View of Boilers and Furnaces ;—open at top.

A Interior View B Stays

according to the fancy of the manufacturer—scarce two being alike; but the more simple in construction the better. The boiler consists of several parts; viz. the cavity which contains the water; the furnace; and the flues; to which may be added the steam chest, for marine engines. The top and side plates are strengthened and supported by stays, as shewn above, for the better security against the danger of collapsing; the stays, however, are placed variously; some upright, from the bottom to the top, for the support of the roof; some diagonally; and others stretch across and separate the fire-places from each other. The flues pass through the interior of the boiler and are surrounded by the water, which circulates over and under them, and prevents their being destroyed by the action of fire within-side them; the top and sides of the furnaces are protected in the same manner; as likewise the ash pits. The fire-bars should be of wrought iron, as they can then be straightened or repaired, &c., when

damaged, on board; and the best distance of placing them is about $1\frac{1}{2}$ inch apart. The furnace, which is in front, communicates with the flues by a contraction at its further end, called the "Bridge," a somewhat sharp elevation, at an angle of near 45°, which serves to accelerate the draught. The steam chest is connected with the boiler, and placed over it for the reception of steam as it is generated in the boiler. The chimney stack passes up through the steam chest, having its step, or lower extremity, fitted to the flue within the boiler, and serves for the escape of smoke, as well as for the increase of the draught.

ANGLE IRONS

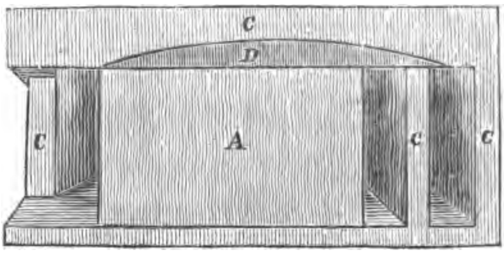
Are another portion of the boiler; and are strips of iron at the angles of the plates, which they join together, and between which the water is contained within the boiler.

SMOKE JOINTS*

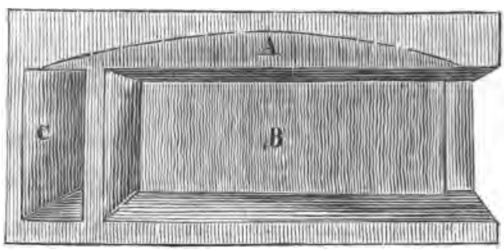
Are the junction of the flues of the boilers when placed

* If instead of clay, a cement of red lead and cast iron boreings, worked up like putty, were substituted, it would be far more durable, and even

in position side by side, &c., leaving a passage, or flue, for the flame and smoke to circulate as they pass to the chimney. The boilers, when so placed in position, are cemented together with clay, which being liable to crack



A Side to be attached to the annexed Flue
C Water D Smoke Joint



A Smoke Joint B Flue to be closed by the annexed side
C Interior View

and crumble by the working of the vessel, exposes her to the hazard of catching fire, either above or below the flue, by the flame exuding through such aperture, if the clay cracks. This is an unnecessary exposure of the vessel to the danger of the fire, and not adopted by all boiler

difficult to separate. This is also particularly applicable for stopping leaks in boilers. It should be allowed twenty-four hours to harden.

makers; some forming their flues within the several boilers without making them dependent on the side of the contiguous boiler; whilst others leave one side open, and to be afterwards closed by the side of the next boiler. Of the latter class the Messrs. MAUDSLAYS are least exceptionable, as they have fewest smoke joints.

SYPHON, OR SAFETY PIPE, TO PREVENT EXPLOSION OF BOILERS.

Always supposing the boilers to be made of the best materials explosion can only arise from one of the two* following causes; viz., either "overloading the safety valves," or, which is far more likely (and by no means an uncommon case) from "neglect in regard to keeping up the proper supply of feed-water;" whereby the water becomes so low within the boiler that the steam has, in consequence of the continued intensity of fire-heat underneath, become supercharged with caloric; and, at the same time, the flues made red hot. The steam is thus decomposed and converted into hydrogen-gas; and, as the supply of feed-

* A third, though not of common occurrence, is that of the ball within the condensing bulb of the waste steam pipe, getting loose, and by the force of steam, becoming jammed in the mouth of the pipe, as it is now formed, but which should be bell shaped, to admit of the ball being forced out.

water has been impeded, there can be no longer a check (so long as it is undiscovered) to its expansion, wherefore explosion must follow.

As a preventive to both these casualties, a pipe should be fitted within the boiler, having the mouth of one end of it, about 4 or 5 inches above the fire-flue; the pipe to pass upwards through the steam chest to a given height, (which shall prevent the steam pressure from *prematurely* forcing the water up to the bend) then doubling downwards, so that its opposite end shall open into the engine room.

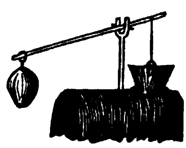
By this contrivance, the pipe may be so proportioned in height, that should steam pressure at any time amount to such elastic power as tends to endanger the boiler, by the safety valve being over weighted, or from other cause, not lifting, that pressure acting upon the surface of the water, may be adequate to forcing the *water* over the bend in the syphon, which, pouring into the engine room from the further extremity of the pipe, would give notice to draw the fires and open the valves, as the steam is then getting too high.

In the second case, as the mouth of the pipe is proposed to be 4 inches above the fire-flue, should the water, from any impediment in the "feed-pipe," or when "blow-

ing off the boilers," get below the orifice, *steam* (not water in this case) will rush through, and by its sonorous noise, not only will the negligent, but those moreover who may have been too confiding in the *water guage,* without the precaution of occasionally shaking it, or testing the cocks, be roused and warned that all is not right; and there will then be 4 inches of water remaining over the flues, to prevent any ill consequences, either of explosion of the boilers, or of destruction of the flues. This deficiency of "feed" is by no means an uncommon occurrence ashore or afloat, as inexperienced Engineers are too apt to rely on the indication of the water guage glasses, which from salt, &c., will corrode more or less; hence arises the damage in the boilers, by burning the flues, collapsing, blistering the plates, &c., &c.

This pipe is obviously applicable to low-pressure boilers only; the elastic power of high-pressure steam would force the water through at all times.

SAFETY VALVE.



A weight fitted to the aperture on the top of the boiler for the escape of steam, after it shall have attained an elastic force beyond that which it is thought prudent

to expose the boiler to; and it is loaded, accordingly, with a weight of so much per square inch; thus,—diameter $4 \times 4 = 16 \times 3$ (for pressure of steam) $= 48$ lbs, the load on the valve.

The simplest form of safety valve, is perhaps that of the steel yard; and this weight is extended from, or drawn near to, the valve, as it is to be increased or diminished. The importance of this safeguard may be appreciated when we learn from the experiments of Mr. WATT, that the active heat "doubles itself in every succeeding three minutes, if the steam be retained in the boiler without escape, and a good fire under it," (as would be the case when over weighted, or when there is a deficiency of water within the boiler) coupled with the evidence of Mr. PERKINS, that "steam may be raised to such a height, that the superabundant caloric has been found to heat the upper surface of a boiler *red hot.*" Now, the common square boiler from its form, is incapable of sustaining any very great pressure; it is said to be calculated to work at 10lbs per square inch, and to be capable of resisting 40lbs; though seldom worked beyond 3½lbs. No prudent Engineer however would venture to exceed 5lbs pressure; whereas the round boilers, in common use on the Cornish mines, have been worked to four or five hundred pounds to every square inch on the safety valve; though experience has taught, that 45lbs

is the maximum at which they can be worked to the best profit.

There are many advantages attached to the round boilers to counterbalance any objection to their containing less water than the square formed; as by making them longer, we obtain that desideratum also; but for strength, durability, simplicity in the formation of the flues, and *no smoke joints*, they are incomparable; then again, resistance against steam pressure to an enormous extent, in case of accidents, from either a redundancy of steam, or a paucity of water; also the facility with which they can be covered over, so as to prevent the escape of heat by radiation, and consequently the saving of coals; but above all, the advantage afforded by them of working steam at *any degree of pressure*, suitable to the work to be done, from 3lbs to 300lbs per square inch if required; and that too without the slightest apprehension of danger. The safety valve should be capacious; not less than 6 or 7 inches diameter, to allow a free escape of steam when blowing off.

PAINTING THE SMOKE FUNNEL.

It is surprising that the Government Steamers have not their funnels paid over with the same "anti-corrosion"

substance, which is used in the Ordnance Department, for the guns, shot, shells, &c.; all of which are exposed to the action of the weather, unsheltered, for years, and yet never suffer in consequence; whereas our funnels do materially. Nothing as yet tried has been found to resist the effects of salt water, heat, and weather.

BLOW THROUGH VALVE, X.

In order to perfect the vacuum, it is absolutely necessary to free the cylinders from all air and water which may have accumulated within them, prior to starting the engines. To this end, a blow through valve is fitted to the condenser; the injection cock is first shut off, and the steam valve being then opened, the steam from the slide jacket rushes into the cylinder, through the eduction pipe, and thence to the condenser, and out at the blow valve; carrying with it all air and water which it may have met in its progress; and when all is right for effectuating the vacuum, steam alone will be seen to issue from the blow valve; after which the injection cock may be opened if about to start.

STEAM CHEST.

This on board ship is a necessary appendage to the

boilers, though not required on shore. It is placed over the boilers as a reservoir for the concentration of steam as it rises from within them; otherwise, owing to the motion of the vessel, the water, as well as steam, would be apt to flow through the steam pipe into the cylinders. Even with this precaution an apron, or perpendicular tube, placed before the mouth of the steam pipe, within the steam chest, is found serviceable as a preventive. From hence are the cylinders supplied by means of a steam pipe. But instead of one general reservoir, it would be vastly beneficial were each separate boiler furnished with its own particular steam chest; or, which would amount to the same advantage, that the communication between every boiler, with the common reservoir, be so arranged, that the steam may be shut off from it, or admitted, as may be advisable; it being a case of frequent occurrence, that from various motives, it becomes desirable to work but one, or perhaps two boilers, only; in which case, it is necessary to exclude the steam generated from the working boilers, from that or those, which it is wished to overhaul, repair, or economise on. The steam chest should be capacious to insure a constant supply of steam.

STEAM PIPE

The grand duct for the conveyance of steam from the

steam chest into the cylinders. As it is of considerable length (more or less, according to the position of the cylinders), the steam is liable to the action of the cold atmospheric air which surrounds the pipe, and consequently to condensation, in a greater or less degree, in proportion to the temperature during its passage from one place to another. To obviate which a packing of saw dust, of about four inches deep, encircling the pipe, and inclosed within a casing of sheet iron, is greatly advantageous. In heavy weather when the vessel pitches, or rolls violently, should the boilers be somewhat overcharged, the water is liable to flow into the steam pipe, and to find its way into the cylinders; to prevent which, a short pipe should be fitted within the steam chest, just before the orifice of the steam pipe. But in *placing* the steam pipe, for the supply of the cylinders, they should have such an angle of elevation from the steam chest towards the cylinders as will insure not only the prevention of this flowing of water, but, likewise, shall cause whatever condensed steam may have been deposited in its passage to run back into the steam chest, and thence to the boiler, instead of allowing it to be driven forward into the cylinders.

GUAGE COCKS AND WATER GUAGE GLASSES.

Guage cocks are fitted to the fronts of the boilers; and

serve to shew what is the state of the water within them; that is, whether the proper supply has been kept up or not by the feed-pipes. The boilers should be about two thirds full, or be on a level between the two upper cocks, which will be known by turning each alternately; the top one should send forth steam, and the under cock, water.

The water guage glasses, are likewise fitted to the fronts of the boilers, and present to the eye at once the height of the water within. They are glass tubes fitted into sockets, and communicating with the water inside; which, flowing into these tubes, and of the same temperature, demonstrates the state of the feed, without the risk of breaking the glasses. The one set of guages serve as checks on the other, as the cocks should be occasionally tested as well. If steam should issue from both cocks, there is then too little water within the boiler; should water pour forth from both, on opening them, there is, in that case, too much. One should give water, the other steam.

The guage cocks, as generally fitted, are defective, inasmuch as that when fresh water comes in contact with salt water the ebullition is so great, that the most experienced Engineer may be deceived as to the state of feed. The same may be observed of water which holds different

substances in solution, that at times repulse each other.* To remedy this, it is only necessary to bring a pipe, bent at each end, of about two inches diameter, outside of the boiler in front; having a passage of communication as near as possible at the top and bottom of the boiler. By this means the water, always flowing upwards from the bottom, is not effected by the ebullition on the top of the tubes; whilst the steam, acting alike at top and bottom, always gives the true height of water.

BLOWING OFF PIPES.

Each boiler has a blow pipe attached to its under side and leading to a main blow pipe, in front of the boilers, and under the flooring of the "Stoke-hole," and which communicates with the sea through the bottom of the vessel. This is for the purpose of freeing the boilers of sediment, &c., which would otherwise accumulate at the bottom, and eventually prove the destruction of them. Great care is required in the performance of this operation of "blowing off," as should too much water be suffered to

* This effect is perhaps attributable to the higher degree of heat at which salt water boils under any given pressure, compared with fresh water; the pressure not being allowed to increase, the ebullition does so for a short time; or rather, the heat due to the pressure of the steam, from salt water, is suddenly given out to a mixture which requires a lower pressure for the formation of steam of the same pressure.

escape at once, the flues would become exposed to the fire and be destroyed. As a preventive, it has been proposed to fit a pipe within the boiler from about 4 inches from the top of the fire-flue which, passing upwards through the steam chest to the height of the top of the waste water pipe down again into the engine room, will avert the accident of blowing off *too profusely*; as should the water get below the orifice of this pipe the *steam* would then find its way in, and rushing through the pipe cause such a noise in the engine room as could not fail to warn the Engineer that he was exceeding the bounds of prudence. A leaden plug is sometimes fitted to the boilers over the furnace, so that as long as there is a sufficiency of water within the boilers to cover the plug all is secure; but the moment the water gets too low the lead is melted by the fire, leaves the hole it occupied open, and the steam rushing through extinguishes the fire, so as to prevent damage. These precautions, however, are not always attended to, H. M. S. V. Volcano having suffered on more than one occasion for want of such preventives. See article "Safety pipe."

But one blow off pipe is not sufficient; each boiler should have at least two, and each blow off pipe should discharge itself independent of any main pipe, as should accident occur to the main pipe the branch pipes cannot free the boilers. Nor is a main pipe necessary; but if

continued it should be of sufficient diameter to receive the joint contributions of all the branch pipes, if opened at the same time. Mr. KINGSTON, of the Engineer Department, in Woolwich Dock Yard, has introduced, of late, a valve into the main pipe, which may be lifted out by the Engineer in case the common valves, by expansion, should be unmanageable; it is frequently found difficult to turn them, and this additional valve cannot fail to prove a great safeguard.

FIREBARS

Should be made of wrought iron, rather than of cast; and if they are carefully shifted from time to time, placing such as were in the middle, at the sides, and vice versa; and taking care that no hot cinders be suffered to remain *under* them, they will last long. The stokers should rake away the fire as it falls through, otherwise the fire heat on top of them, with the fire heat below, will soften, if not actually melt them; and the superincumbent weight of coals cause them to droop downward. They should be placed at about 1½ inch apart. When made of wrought iron there is no difficulty in repairing them if broken or damaged, or straightening them if out of shape, by the men belonging to the engine room. As the cinders fall through the bars

the firemen should separate them from the clinkers and ashes, and mix them in with small coal.

CANNOT KEEP STEAM.

This must arise from a palpable defect: either bad coals; too small a fire surface; leakage; inadequate steam chest as to capacity; or the same in regard to the boilers; for if there be not sufficient space between the crown and the water within, a sufficiency of steam cannot be generated. It may also arise from inattention to the feed-pipes: If the feed be too great, the redundancy of cold water not only chills and checks the ebullition, but occupies that space which is required for generating steam; if it be too little, the quantity of water which is in the boiler diminishes every instant, and cannot, of course, be adequate to the supply of steam required. We have, therefore, only to ascertain the *cause* of the defect to know what remedy is to be applied.

PADDLE SHAFTS.

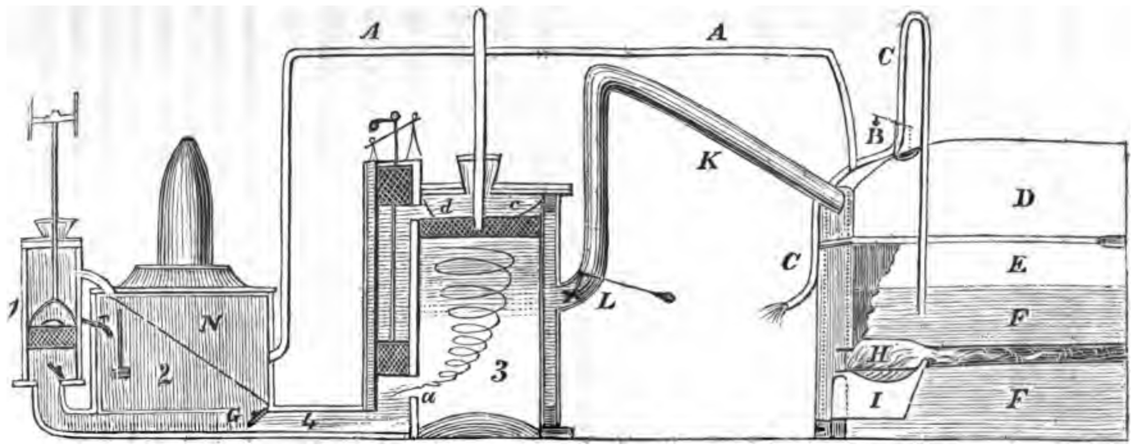
Were small rollers inserted into the bearings of the paddle shafts, the opposing friction would be lost and

considerable velocity thereby gained, besides being attended with less wear to the shafts and bearings.

DISCONNECTING.

The time occupied in, and the inconvenience attending, this operation, as at present performed, is an insuperable bar to the advantages which a more speedy and simple system would inevitably afford for the "economising of coals,"—by taking advantage of every spirt of a favouring breeze, and having recourse to sails only when "expedition" is not a material object. To this end I have, in conjunction with Mr. A. Sleigh (Master's Assistant in the service), formed a model, the plan of which is that of a simple clutch in common use for cranes, millwork, &c., whereby the paddle wheel is disconnected from the engine by merely sliding back the clutch, and again connected by sliding it forward. One hand can do it in a few seconds; and the clutches being withinside the engine room, that is, on the inner side of the coal boxes, I cannot apprehend any objection to its application, as no extra pressure can take place on the outer bearing of the paddle shaft. Our first proposition was the application of cogwheels (likewise attached to the common crane); but upon watching the boring of a 90 inch cylinder there was evidently a shaking or jarring of the cogs: and, further-

more, the *friction* would have caused the loss of one, if not two, revolutions of the wheel per minute; neither of which objections are, I imagine, applicable to the "clutch;" the one locking into the other and revolving together on the axis of the paddle shafts. If adopted, the readiness with which the paddle wheel may be disengaged from the engine without any, the slightest even, inconvenience, together with the expedition with which the wheel can again be put in gear, will lead to the frequent practice of taking advantage of every blast of wind for the spread of canvas, and of husbanding the coals, by "banking up the fires," during the continuance of the breeze. Every hour so taken advantage of will be attended with the saving of between 14 and 16 bushels of coals on the average; that is to say, 2 or 3 bushels per hour will be amply sufficient to keep the fires in a condition for immediate action whenever it is required to have recourse to the wheels. On long Atlantic voyages, now becoming common, this will lead to an amazing saving of fuel; say four hours a day only, for a week, will amount to upwards of 400 bushels, or near 16 tons: and so in proportion for any other period.



1	Section of Air-pump	C	Safety pipe	K	Steam pipe
2	Condenser	D	Steam chest	L	Throttle valve
3	Cylinder	E	Steam	N	Hot water Cistern
4	Eduction pipe	F	Water	*a d*	Apertures leading from the Cylinder into the Eduction pipe
5	Boiler, Steam chest, &c.	G	Foot valve in the Condenser	*c*	Piston
A	Feed-pipe for conveying water again to Boiler	H	Fire		
B	Safety valve	I	Ash-pit		

EXPLANATION OF THE PLATE.

If the piston *c* is at the bottom of the cylinder (but *shewn* to be at the *top*) and the aperture *a* (below) open, steam will rush from the steam pipe into the cylinder 3, and force the piston upwards, there being a vacuum on the upper side of it, and consequently no resistance. At the same time, the piston of the air-pump 1 will rise, and produce a partial rarefaction within the condenser 2. As soon as the piston has arrived at its due elevation,* the aperture *a* must be shut, by the descending of the slide valve (worked by the eccentric rod, acting on the traverse shaft) and *d* opened; when the steam from the cylinder will rush *from below* the piston through the eduction pipe 4, and into the condenser 2, where coming in contact with the cold water (supplied by the injection pipe, not shewn) it is neutralized, and produces a vacuum, which enables the piston now to exert its *downward* force, by the steam which enters at the top *(d)*, whilst that at the bottom of the piston is passing out; and a similar process

* Effected by the slide valve, worked by the eccentrie rod, which comes from the intermediate shaft down to the way shaft. The above diagram represents the piston when arived at the top of the cylinder, and the D slide having moved up also, opens the aperture *d* for the admission of steam above the piston, and closes the aperture *d* for *admission*,but opens it for the escape of steam from under the piston; and this escape is occasioned by the air-pump lifting, and drawing the steam through the foot valve at G; when, meeting the injection it is converted into water, and in that state drawn up by the pump, and delivered into N the hot-well.

takes place above. During this time the air-pump I will draw off whatever air or condensed water may have been deposited in the condenser, and transfer it to the hot water cistern N; thus preparing the condenser for the formation of another vacuum, which it is enabled to do by the injection pipe keeping the cistern constantly replenished. The separation between the hot-well and condenser is shewn above by the diagonal line; and the steam is represented rushing from the cylinder into the eduction pipe; being drawn by the air-pump.

PROPORTION OF FUEL TO HORSE POWER.

It is certainly desirable that there should be established some criterion for estimating the performances of different vessels at a given expenditure of fuel, if it can be done; but this is vastly difficult. How can we, for instance, compare the expenditure of any two or three steamers with each other, when each is supplied with a different species of coals, even supposing the vessels themselves to be built on the same model, and their machinery to be furnished by the same Engineers. In stating the expenditure at so many pounds an hour per horse power, it seems to be altogether lost sight of, that coals are of very different qualities, and that those different qualities produce widely different results; thus, one species of coal weighs 70lbs, whilst another averages 80lbs, and a third

kind as much as 90lbs per bushel, measure, which is about 2½ cwt. per ton, difference, or 5 cwt. between the first and the last qualities (see "article Weight of Coal"). In the second place, the results of their heating qualities are not in the proportion to their specific gravities, but in that of their carbonacious combination with bituminous and other matter: and, again, the boilers, although of the same capacities for the engines of a given power, differ materially in form and construction according to the manufacturer, and consequently that they also will cause a dissimilarity in the consumption of coals even of the same quality, in accordance with a good or a bad construction of their internal arrangements. We will say nothing as regards the qualification of the stokers, as these may be good and bad in each vessel, and the *average* consumption only is taken as the estimate.

But before such criterion can be established, it will be necessary to demonstrate the best form of construction for boilers, furnaces, and flues; secondly, the most approved proportions for an engine room, according to the size of engines, for inducing draft; and, thirdly, which species of coal is best calculated to produce a given intensity of heat (not the *greatest* intensity of heat, see article "Anthrocite, or Stone Coal"), with the least loss by dust and ashes. Until these points are determined, I cannot see how we are to judge of the merits of any two Steamers in regard to the expenditure of coals per horse power.

STEAM.

The particles of all bodies are subject to the action of attraction and repulsion, and are more or less solid as the attractive force predominates. By excess of heat, however, those particles are caused to expand, and the attractive principle to diminish in proportion, until at last the cohesive affinity is altogether destroyed; after which, those particles so far from retaining their original compactness, will then repel each other, and thus vapour is formed. By the further extension of heat, not only does this vapour rise more rapidly, but unless steam of a superior elastic power is that to be made use of, the water itself will be driven off from the iron on which it had rested whilst boiling, and leave the iron exposed to the effects of the fire. But high-pressure steam will prevent this effect, as its superior elastic power pressing upon the surface of the water within the boiler forces it down, and keeps it in contact with the bottom of the boiler, in proportion to the quantum of pressure, or load on the safety valve employed.

Now all fluids press equally in all directions, consequently air, which together with steam, is a fluid, partakes of this property. We shall, therefore, set out with stating the well known fact, by way of data, that the pressure of the air, or atmosphere, upon all bodies, is with the weight of 15lbs on every square inch; that is to say, on the top, at the sides, and at the bottom of any square substance, of one inch measurement each way. Steam in like manner, is governed by the same principles; but its pressure is made to vary according to circumstances, and is subject to control.

Now as the power of the steam engine depends upon the highly elastic force of steam, it will be necessary to state that the specific gravities of both solids and fluids, depend upon the agency of heat, either in an active or latent state.* Water at the temperature of 212° under the ordinary pressure of the atmosphere, is converted into steam of the same temperature (212°), but with a specific gravity 1800 times less than that of water, and an elastic force whose pressure is equal to that of the atmosphere; that is, 15lbs on the square inch.

* *Active or sensible heat*, is that which is indicated by the thermometer, and palpable to the touch; *latent heat*, is that quantity of heat which is essential to the fluid state; deprived of which water becomes ice, and equivalent to 140 degrees, that is, raise the same quantity of water to 140 degrees. Latent heat is not indicated by the thermometer, and from that circumstance is so named.

Such is the elastic force of steam under atmospheric pressure, but remove this pressure, and water may be converted into steam at very low temperatures. Thus, if we suppose the atmospheric pressure to be removed from the surface of the earth, it is not difficult to prove, by experiments, that there is sufficient heat in water generally to convert it into steam. By way of exemplification: suppose we represent the heat in water by a coiled spring, the active principle of which is rendered latent by a weight of 15lbs per square inch, which we will call "atmospheric pressure." This weight upon the spring, by its pressure, will prevent its expansion precisely in the same way that atmospheric pressure prevents the heat contained in the water from expanding, and thereby converting the non-elastic into an elastic fluid. Or, to prove this experimentally, take water, the temperature of which is, by the thermometer, 112° (instead of 212°, or the boiling point) place it in a vessel open at the top, on the pump plate of an air-pump; over this place a closed-top receiver, the base of which must be perfectly air tight on the pump plate: exhaust the air from the interior, and on a good exhaustion being made, the water will be seen to bubble and boil in the interior vessel.

As, however, air-pumps may not be in the possession of all, the above fact may be proved in a more easy manner, and equally satisfactory. Thus, take a common

Florence oil-flask, quite clean, into which insert about three table spoonsful of water; then place it over a lamp until it boils; or, in other terms, until the temperature of the water within the flask is raised to about 212° (for this depends upon the pressure of the atmosphere at the time of making the experiment), after which remove it from the lamp, and, whilst yet in a boiling state, put a cork, fitting well, into the mouth of the flask, and the water will immediately cease to boil. But let the flask be now partly immersed in cold water, and, without any additional heat, it will be seen to boil a second time.

The principle may be thus explained: the cork being placed in the mouth of the flask, the steam, like the spring when pressed by the weight, is prevented from escaping; and, consequently, it presses on the surface of the water in the interior, precisely as the weight did on the spring, and by such pressure prevents its expansion or ebullition; but on the flask being immersed in cold water the steam in the interior becomes again condensed, and the pressure being thus destroyed, a sufficiency of heat still remains in the water to generate steam a second time, and exhibits the phenomenon of again boiling.

From these, and other experiments, it is evident that the atmosphere is an opposing force to the formation of steam. Even on the surface of the earth we find that

water does not always boil at the same temperature. It is usual to say that 212 degrees is the temperature at which water boils; but to such statement we should add, "under a mean state of atmospheric pressure." Let us endeavour to exemplify this:—it is generally known that the altitude of the quicksilver in the barometer will fluctuate from 28 to 31 inches. We also find that if the pressure of the atmosphere be so light as only to raise the quicksilver to 28 inches, water, placed in an open vessel on the fire, will boil at 209 degrees of temperature; but if, on the other hand, the pressure be so great on the part of the atmosphere as to raise the mercury to 31 inches (rarely the case), water will not boil until it attain a temperature of 215 degrees. Hence the boiling point of water being set down at 212 degrees, means to imply that under a mean state of atmospheric pressure (or which is the same thing, when the barometer stands at 29½ inches), that that is the temperature at which it boils.

The immediate cause of the phenomena of heat, says Dr. Ure, is motion; and the laws of its communication are precisely the same as the laws of the communication of motion. And as all matter may be made to fill a smaller volume by cooling, it is evident that the particles of matter must have space between them; and since every body can communicate the power of expansion to a body of a lower temperature, that is, can give an expansive

action to its particles, it is a probable inference that its own particles are possessed of motion; but as there is no change in the position of its parts as long as its temperature is uniform, the motion, if it exist, must be a vibratory, or undulating, motion; or a motion of the particles round their axes; or a motion of particles round each other. Hence the mobility, or active movement of the particles of fluids and their reciprocal independence of each other, permit them to change their places whenever they are expanded, or contracted, by alterations of temperature; and hence also the immediate and inevitable effect of communicating heat to the under stratum of a fluid mass, or of abstracting it from the upper stratum, is to determine a series of intestine movements. The colder particles, by their superior density, descend in a perpetual current and force upwards those rarefied by heat. When, however, the *upper* stratum primarily acquires an elevated temperature, it seems to have little power of imparting heat to the subjacent strata of fluid particles; and then only through the *conducting*, and not the *carrying*, power: for water may be kept long in a state of ebullition at the surface of a vessel, while at the bottom it will remain as cold as ice, provided we take measures to prevent the heat passing downwards through the sides of the vessel itself.

Count Rumford entertained a conviction that it was totally impossible to communicate heat downwards through

fluids; but experiments have been instituted, which prove the actual descent of heat through fluid particles by communication from one stratum to another. This communication, unquestionably, is amazingly slow and difficult; whence we are led to conceive that it is an actual contact of particles which, in the solid condition, facilitates the transmission of heat so speedily from point to point through their mass. So that the diffusion of heat through a fluid mass is accomplished almost solely by the intestine currents.

We have already shewn that the density of steam reacts and becomes a *pressure* upon the vaporizing water; so that whether high or low heat, that is pressure, be employed, an equally large extent of surface, or nearly so, is necessary, being about ten feet square per horse power. The rapidity of vaporization is more or less impeded by this pressure, and is retained in a *latent* state; one cubic inch of water forms one cubic foot of steam; the heat evolved from which, is sufficient to heat 6 cubic inches of water to 212 degrees, but cannot be made to rise more than 2 or 3 degrees within the boiling point, unless the vessel containing the fluid be *steam tight* and enclosed within another vessel, forming a jacket, with steam admitted between the two; in which case, water may be brought to 212° in eleven minutes. The principle of PAPPIN's digester is, that steam not being suffered to escape,

presses upon the water, keeping down the ebullition, and preserving the heat in a *latent state.** So, water within the boilers, upon the same principle, may be brought to any degree of heat above 212°; and would eventually burst the vessel containing it, unless precaution were taken to proportion the quantity of heat to the capability of the containing vessel; for though this heat be latent, it goes on increasing in proportion to the pressure employed. Hence the economical properties of high-pressure engines. The increased power of steam so confined as that none of it be suffered to escape, was estimated, by the late Mr. WATT, to double† itself in every succeeding three minutes of time, supposing an uniform good fire to be kept under it. That is to say, steam of an elastic force of 10lbs pressure per square inch, will attain a power of 20lbs in the first three minutes, and 40lbs in the next, and so on; for if the heat be increased in an arithmetical ratio (that is by equally progressive degrees) the elastic force of the vapour will increase in a *geometrical* ratio, or double itself, as above.

The following table, exhibits the elastic force of steam

* A steam boiler of 90 gallons, will keep the steam up for 20 minutes after the fire has been taken from under it; and the water will continue warm for 20 hours longer. A common covered kettle very soon gets cold.

† Every additional 40 degrees of heat doubles the previously existing expansive power of vapor; and this temperature proceeds arithmetically, but the expansion proceeds in a geometrical ratio.—HOWARD.

under the different temperatures, as shewn by the thermometer:

Temperature by Thermometer.	Atmospheres.	Pressure per square inch.	Inches of Quicksilver.	Or feet of water.
°		lbs.		
212	1	15	30	34
250	2	30	60	68
275	3	45	90	102
294	4	60	120	136
309	5	75	150	170
344	8	120	240	272

These principles, however, of the compression of steam, and its increased elastic power, will be more fully elucidated hereafter, when we come to explain its application to the engine, and the manner of its introduction into the cylinders.

EXPANSIVE ACTION,

Or steam so highly rarefied as that a portion of it, when admitted into the cylinders, may by its elasticity only, be worked with a power adequate to the resistance to be overcome. To effect this, the safety valve is loaded in proportion to the power at which it is intended to work. When admitted into the cylinders, a very small portion of this powerful steam is sufficient, if worked on

this principle of expansion; wherefore it is cut off at a quarter,* a third, or at half the stroke of the piston, as it ascends or descends, and its further admission precluded. The pressure of that portion of steam so admitted, although it enters the cylinder at the power expressed by the load on the safety valve, say 15 or 20lbs per square inch, yet, from the instant it is shut off from further ingress, it commences its expansion, and thereby diminishes its power in a progressive ratio, which is continued until the piston shall have completed the stroke, up or down, and the accelerating force is consequently lessened in the same progressive ratio. Were steam of this powerful description used without the principle of expanding it, after admitting a given quantity, it would cause the pistons to work too violently, and might eventually shake the engines; but to prevent this consequence, as well as to effect a good condensation, the valve by which it passes into the cylinder is regulated so as to close, by the time the piston shall arrive at a quarter, or third, &c., of its

* High pressure steam of even 15 pounds per square inch only, cannot be condensed in the common condensing engines, wherefore it is necessary that it be *cut off* as above, in order to reduce its power by expansion, and prepare it for condensation. The opposers of high pressure for ship board, argue that it will rack the engines to pieces; but by *expanding* the steam, this is obviated; and the grand object of economy is attained; for the saving of steam is the saving of fuel. By cutting it off at $\frac{1}{4}$ the stroke, we save $\frac{3}{4}$ the cylinder full; and this redundancy, instead of being thrown away by the waste steam pipe, is retained in the steam chest and boilers, and through the *conducting* power of liquids, the caloric is carried *downward* and helps to boil the water.

length upwards or downwards in the cylinder, and no further quantity can be supplied until the returning stroke of the piston causes the valve again to open.

The usual mode of applying steam on ship board is on low-pressure principles, of from two to three pounds weight per square inch, as the load on the safety valve. In other words, steam emitted from water, at the boiling point of 212°, is equal to the pressure of the atmosphere, and estimated at 15lbs per square inch. But that a constant and uniform supply of steam to the cylinders may be maintained, the safety valve is loaded with a weight as above, of about three pounds per square inch, which by compression to that extent, retains a supply of steam in the boilers for that purpose; and that admitted into the cylinders is, by that much, superior to steam, equal only to atmospheric pressure. But since the application of steam on high-pressure principles has been introduced on board ship, the safety valve has been considerably increased in its loading, and proportioned to the power of steam to be used, and the term "expansion" has been applied as explanatory of the mode of its action; though, from its very nature, all steam, whether high or low-pressure, is necessarily expansive in its action, in a greater or less degree. When, however, it is to be used on the newly-termed expansive principle, it must be so rarefied by compression in the boilers, with a load of

fifteen, twenty, &c., pounds, per square inch, on the safety valve, as shall raise the elastic power of the steam that much *above* the usual atmospheric pressure; for were there no confining pressure at all upon the aperture of the safety valve, the steam, as soon as it ascended, would be equivalent to the pressure of the common atmosphere. Being charged with this superior elastic power, a very small portion, when introduced into the cylinders, is sufficient to set the pistons in motion, and whilst extending its volume (although progressively diminishing its strength by expansion) to take them to the full extent of the stroke. Upon the low-pressure principle, the whole quantity of steam emitted from the boiler, or steam chest, rushes at once into the cylinders, and from its impure, weak, or watery quality, that quantity, when the engines have any thing like resistance to overcome, is not too much for the purpose of completing the full length of the stroke of the piston. But the power of steam being thus enhanced by rarefaction, renders it expedient to regulate the quantity of high-pressure steam to be thrown into the cylinders (of condensing engines), by means of a valve fitted expressly for the purpose, and called the "Expansive Valve,"* placed at no great distance from the present

* Steam may, however, be used expansively, without attaching the expansive gear; as it only requires to shut up a part of the passage which admits the steam into the cylinder. For instance, say steam of 15lbs, is that in use, shut off two thirds of the passage, and one third only will be open for the admission of steam; which quantity will expand to thrice its

throttle valve, and which is made to open and shut with a velocity, or retardation, proportionate to the required supply. When working at a maximum, its velocity may be compared to the snapping of the fore-finger and thumb. The moment this steam enters the cylinders the expansive action commences; and the quantity, though small, spreads its volume and fills the cylinder by its elastic quality, and follows the piston in a progressive ratio of diminishing force to the bottom, or to the top, as it may happen to be rising or falling. Thus, for instance, we will say a working cylinder of 36 inches, with a 4 feet stroke (that is, the length of the piston rod within the cylinder), and steam, without consideration of atmospheric* pressure, of 15lbs per square inch upon a vacuum, will require about 9 cubic feet of expansive steam

bulk, and prove equivalent to 5lbs pressure per square inch. In like manner, any other proportion may be adopted, as thought necessary; but this would only be, what is called, "wire-drawing;" and not in any way comparable to the proper adjustment of expansive gear, which is worked by the engine itself.

* Diameter 36×36=1296×48 (4 feet stroke)=62208÷1728=36 cubic feet, as the contents of such a cylinder; and the double acting engines (alone used on ship board) are worked by steam only, admitted both above and below the piston; and not by the introduction of steam below the piston only, depending upon atmospheric pressure for the returning stroke. Wherefore a 36 inch cylinder, as above, will contain 36 cubic feet of steam when full, cut off at a quarter the stroke, admits only one fourth of that quantity or 9 cubic feet; consequently as that quantity, by its expansive action, will suffice, 27 cubic feet *are saved* and retained within the boiler in a latent state, and contributes to heat the fresh feed-water which is constantly flowing in, without more addition of coals, than sufficient to keep the fires up.

within the cylinder, if cut off at a *quarter* the stroke; and this quantity will act with the force of 15lbs for the first foot of descent; for the next foot 7½lbs; for the third foot 5lbs; and by the time it has reached the fourth foot, or bottom of the cylinder, three and three quarters. And though in the above example we have cut it off at quarter the stroke, this is optional, as the power may be *increased* or *diminished* at will, proportionate to the work to be done, by admitting a greater or a less quantity of steam at the time; and, if need be, as the boilers are *cylindrical*, the safety valves may be further loaded to *any extent required* beyond 15lbs per square inch; or, if not choosing to work so high as 15lbs the pressure may be diminished as low as wished, 2½ or 3lbs per square inch. This cannot be done with the *square* boilers; the 3 or 3½lbs steam, or other proportion, cannot be *increased* beyond 5lbs, with any safety; 6lbs pressure would most probably burst the boiler; and the steam, when admitted, continues to follow the piston all the way up or down, in the same stream as when first let in, and with the same force at which it was generated, without the least reservation of power for any sudden or unlooked for exigency; such as occurred on the occasion of the Druid being towed out of harbour by the Echo. See article "Velocity."

With this illustration of expansive action, and by the aid of the following scale, the relative advantages of its

application in a greater or less degree (according to the resistance to be overcome) over the pressure of the atmospheric air, may be easily deduced: viz.—

Steam predominating over the pressure of the atmosphere upon a safety valve, if its elasticity is equal to	Will require to be maintained by a temperature equal to	At which heat steam can expand to about one additional bulk for every 15lbs	
lbs	°		
5	227		And yet continue equal in its elasticity to the pressure of the atmosphere; and by small additions to the temperature, an expansive force may be given to Steam, so as to equal 400 times its natural bulk; or in any other proportion, provided the vessels, or cylinders, are strong enough to contain it.
6	230		
7	232	½	
8	235		
9	237		
10	239		
15	250	1	
20	259		
25	267		
30	273	2	
35	278		
40	282		
45	289	3	

So that steam which predominates over the pressure of the atmospheric air upon a safety valve of, say 30lbs upon a square inch, will require, as per scale above, a temperature of 273°; at which heat it can expand twice its own bulk, and still retain an elasticity equal to atmospheric pressure.

On ship board this application of steam is not common; but amongst the mines in Cornwall the practice is general.

The economy* of this mode of applying steam will be apparent from the following statement out of many.

On *Unity Mine*, where the same engine has stood for the last 50 years, and which, until of late, was worked on the old principle of 2½ to 3℔s, and the *square* boilers used, the consumption of coals was estimated at *five thousand nine hundred bushels a month.* Since, however, the introduction of the recent improvements of *round* boilers† (absolutely indispensible for resisting steam of great power) and high-pressure steam, working at 25℔s per square inch only, the consumption of coals is but *one thousand nine hundred bushels a month;* which is not only a saving of four thousand bushels monthly, but is, moreover, absolutely doing more duty than formerly. These advantages are entirely to be attributed to this recent

* It is self evident, that by cutting off the steam at one half, one third, or a quarter the length, or capacity of the cylinder, we consume but half, third, or quarter of what it would contain, instead of its being filled; consequently the surplus being retained within the boilers, renders a less supply of fuel necessary; there being no necessity to force the fires for continuance of the required contribution of steam for the succeeding strokes of the piston, especially as the caloric of this superior steam helps to convert the fresh additions of feed-water into vapour.

† We cannot too strongly impress the advantages of round boilers; they may be worked on low-pressure principles precisely as would be the square boilers;. but any neglect of feed-water to the latter would lead to explosion after the steam pressure exceeds 6 or 8℔s per square inch; whereas the cylindrical boiler is capable of sustaining a pressure of three, four, or five *hundred* pounds.

mode of applying steam, and not to any alteration in the engine, beyond the addition of the expansive gear requisite for regulating the supply of steam to the cylinder; for since the days of the great WATT, the engine has undergone no change in point of principle, whatever it may have done in form or compactness. It only remained to bring this stupendous piece of perfection into operation at the least possible expense; and notwithstanding the multiplied experiments, and the meritorious exertions of numerous individuals, we yet know of no medium, whereby this can be effected of less cost than fire and water; so these elements are still had recourse to; and in process of time the ingenious Mr. WOOLF had discernment enough to see the advantages to be derived from increasing the power of steam by superior pressure.

It is true that advantages to the same extent (that is, bringing down the consumption so very low) as those just enumerated, cannot for obvious reasons, be attained on ship board, though they may in a considerable degree; for notwithstanding the predictions of many very able Engineers "that the expansive action of steam was inapplicable to the rotatory movement of the paddle wheels of a vessel," from the supposed difficulty of introducing it into the cylinders, top and bottom, as also of effecting an efficient condensation; the late Capt. KING, of the Packet Establishment at Falmouth, aided by Mr.

Ward, a very able practical Engineer, most successfully combatted the difficulties, and proved its applicability on board ship; and H. M. S. V. Echo was fitted on this system under the direction of Mr. Ward; the superintendence of which was entrusted to myself; of which I shall hereafter have occasion to make some mention. On shore, where single acting engines are used for pumping water, &c., there is no difficulty in its application, as it is there introduced below the piston only.

Another objection which was started in opposition to its introduction on ship board, leads me to notice a curious fact attendant on steam rarefied to the height requisite for this mode of applying it, namely, that instead of imparting that intense heat,* which it was imagined would

* The principles and properties of "Latent heat" were I believe first developed by Dr. Black, of Edinburgh, who ascertained that heat absorbed by vaporization is always *less* the higher the temperature at which the ebullition takes place; and less, moreover, by the *same amount* at which the temperature of ebullition is *increased*. Thus, if water boil at 312°, the heat absorbed in ebullition will be less by 100° than if it boiled at 212°; and the reverse, if water be boiled under *diminished* pressure, say 112°, the heat absorbed in vaporization, will be 100° *more* than the heat absorbed by water boiled at 212°. So that whatever heat is saved in the sensible form, is consumed in the latent; and vice versa,—shewing that the actual consumption of heat in the process of vaporization, must be the same, let the temperature at which the vaporization takes place, be what it may. As steam expands, its temperature falls; a portion of the sensible heat being latent; but this latent heat is not indicated by the thermometer; and from which circumstance indeed, it has been denominated "Latent," as it is not sensible to the thermometer. We thus see that heat may exist in two distinct states; in one of which it is sensible to the thermometer; and in the other, not so; and that which is sensible to the thermometer, is also perceptible to the senses, whilst heat which is not sensible

result from this great compression, the very opposite is really the case. For it is only when charged with aqueous particles that steam possesses the power of scalding; consequently low-pressure steam would be insupportable to the hand, if thrust into a body of it; such for instance as that we constantly see issuing from the spout of a teakettle: whereas, steam worked at a pressure of twenty-eight or thirty pounds, is so perfectly free from all watery particles, that the most timid may fearlessly pass the hand through any portion of it, at about two or three inches from the vent of the safety valve, without experiencing any greater warmth than that of tepid water. But the same experiment, if attempted at the distance of as

to the thermometer, is not perceptible by the senses. To exemplify this; ice at 32o and water at 32o, as shewn by the thermometer, *feel* equally cold; whereas the water really contains considerably more heat than the ice, but in a *latent state*. Again, *steam* at 212°, say one ounce, mixed with five ounces and a half ($5\frac{1}{2}$) of water of 32o temperature, forms six and a half ounces of hot water, of the temperature of 212o; but mix one ounce of hot *water* of 212o, with five and a half ounces of cold water of 32°, and the result will be about 60 degrees only. The estimated quantity of heat rendered *latent*, by water in the process of vaporization at 212 degrees, are thus stated;—by SOUTHERN, 945o; WATT, 950°; DESPRETZ, 956°; LAVOISIER, 1000°; RUMFORD, 1004o; averaging 971 degrees; and which, for the sake of round numbers, may be taken as 1000o of latent heat raised from water at the temperature of 212o. In other words, water passing from the liquid state of 212° of heat to the state of steam of the same temperature, 212o, receives as much heat as would be sufficient to raise it 1000 thermomatric degrees, if that heat had been *sensible* instead of becoming *latent*. To maintain water in a state of vapour, the *sum* of both latent and sensible heats cannot be less than 1212 degrees; that is, 212 degrees the boiling temperature, added to 1000o, as above, being the quantity of heat received by water when converted into steam.—DR. LARDNER.

many feet over it, would be attended with very different results; as the steam, in the latter case, would have imbibed so great a degree of atmospheric air by such times as that it shall have risen twelve or eighteen inches in height above the aperture, as again to assume its scalding property.

Not aware of this fact, Engineers were induced to express the opinion that another difficulty which opposed the introdction of the new system on ship board would be "the necessity of increasing the diameter of the air-pumps." Whereas, now that the above fact has been established, the very reverse is the result; and the air-pumps are not required to be so large as heretofore "either on ship board or for land purposes," as very little injection suffices to condense the small proportion of high-pressure steam, admitted on the expansive principle; and it follows, that the air-pumps have not so much water to draw off from the condenser, and to force into the hot water cistern, and from thence through the ship's side, or into the boilers.

The term "expansion" when speaking of highly rarefied steam admitted into the cylinders, on this new principle, is merely a distinctive term, as intimating that high, and not low-pressure steam, is the active agent employed; for all steam is more or less expansive; as water when exposed to the action of heat *expands*, and forms itself into

vapour, which vapour displaces the atmospheric air which previously occupied the space between the surface of the water, from whence the exhalation arose, and the top of the vessel in which it is generated. But the peculiar term "expansive action" is applied only to steam, which, by compression to considerable extent, has been rarefied, and rendered so powerful by its superior elasticity, that a very small portion of it is sufficient for the performance of the duty to be done; taking advantage of the peculiar property it possesses of filling by the expansive principle of unfolding its volume, a larger space with adequate effect; and which, by the time that that effect has been attained, has progressively so decreased, as to be fitted for quick condensation.

The economy derivable from this application of steam is based on the wondrous power it possesses of accumulating strength in a surprising ratio by *compression,* and *detention within the boilers.* This accumulation of power, as already shewn, increases to an extent, and with a rapidity almost incredible. The compression required, and the consequent retention within the vessel containing it, is attained by, and is in proportion to, any increase of weight on the safety valve which may be deemed advisable.

Now, in order to generate steam, whether it be of 3℔s

pressure, or 15lbs per square inch, the degree of firing requisite will be much the same; but to maintain those temperatures (for 3lbs or 15lbs steam) a very different *subsequent* supply of fuel will follow; and a much less quantity will suffice for the purer vapour; because, as the whole quantity of steam generated, of so low a quality as 3lbs pressure, will be in full demand for the work to be done, the boiler must be drained (or nearly so) as fast as that impure steam is obtained; wherefore, to keep up the supply, a continuance of the same degree of firing as was first required, and the consequent large demand for fuel, is indispensible; as any diminution therein, must be attended with a corresponding diminution of the quantity, as well as quality or strength, of such steam. Whilst on the other hand, steam of superior elastic power, after reaching its destined temperature, is doled out to the cylinders, not in an uninterrupted stream like the above, but in proportions only to the work to be done, and the *residue kept back;* which residue although (from the circumstance of its not being altogether retained uninteruptedly in the boilers) it does not "double itself in every succeeding three minutes," as before stated, yet its superabundant caloric combines with the whole mass of water. For "all liquids are capable of conducting caloric; suppose the source of heat, as in this case, to be applied to the surface, the caloric gradually makes its way *downwards,* and the temperature of every stratum progres-

sively diminishes from the surface to the bottom of the liquid." This is termed the *conducting* power, and communicates downward; by the *carrying* power caloric makes its way upwards, and is exemplified in the effects produced through the action of fire upon the water. Hence it is evident that such surplus caloric from *superabundant steam*, beyond the actual demand will render a very diminished supply of fuel, at subsequent intervals, amply sufficient to maintain the wonted temperature, through the operation of the conducting power.

By way of illustration; the water in a common tea-kettle, which cannot be made to exceed a temperature of 212 degrees, will soon cool down if the firing under it be slackened; but that which has been heated to the extent of 250 degrees in a digester (or closed-top boiler) will retain its elasticity of vapour undiminished for a considerable time, notwithstanding a diminution of fire heat. It is from this circumstance we derive economy from this species of culinary utensil; and if applicable on a small scale, it is proportionately so in the more majestic cauldron of a steam engine.

But a prejudice against the use of so powerful an agency as "expansive steam" has yet, I am aware, to be overcome, ere its application on ship board can become general; and this prejudice has been industriously extended by

those very persons who, "knowing the value of its application in point of economy, as well as of imparting superior power *at will*, whensoever exegencies should render it necessary," would most gladly have applied its agency, but that they cannot forgive themselves for having been blind to its applicability on board ship, until shewn by men, not immediately brought up in the mystery of engineering. Had the discovery, or rather the application of the power of expansive steam, to the rotatory motion of the paddle wheels, and its *quick condensation** through the ordinary process, been that of a professional Engineer, instead of a Captain of the Navy aided by a practical working man, we should now know nothing of low-pressure engines, working at some 3 or 4 lbs pressure, and lumbering waggon boilers, which are incapable of sustaining a much greater load, beyond hearsay that such things were, but during the *infancy* of steam only. We should have had justice done to the Government, to the Merchant, and to all parties interested in steam navigation; but perhaps the coal contractor would not have been equally pleased.

The arguments advanced, in opposition to this application of steam, are, that it will shake the engines so greatly

* Without reflecting upon the reduction of its elastic power by expansion within the cylinders, it was asserted that high pressure steam could not be condensed in the common condensing engines, a palpable error.

as eventually to destroy them; and therefore that as low-pressure, or 3½lbs steam, is found adequate to the work required, where is the utility, or even prudence, of hazarding the force of 15 or 20lbs?" To which I beg, in reply, to observe, that by the admission of steam of *any superior power*, in small portions only, and *expanding* that portion within the cylinders, the movements of the pistons are in no way accelerated, consequently there is no chance of racking, or shaking the machinery; and as for hazard arising out of an increased load upon the safety valve, that that is more than merely chimerical, the boilers for such superior steam being cylindrical, or round,* and consequently fully capable of sustaining whatever pressure it is thought fit to load the valves with, even to *hundreds of pounds* pressure per square inch; whereas the common square boiler, now universally adopted on board ship is, proverbially, unsafe in the estimation of every Engineer, who well knows that beyond a pressure of 6 or 8lbs per square inch on the safety valve, such boiler will, to an almost certainty burst. Every Engineer knows that through the "expansive" application of steam, the great object is to economize fuel, by having steam of such superior force as will enable us to make use of but a very small portion for the cylinders, at the same time that we retain a considerable share within the boilers, the latent heat of which communicating with fresh accessions of feed

* See Articles "Safety Pipe; and also, "Safety Valve."

perpetually pouring in, tends to raise its temperature, without any forced exertions from the furnaces.

But it is urged that they do not keep steam, "not having sufficient fire surface." But were those boilers proportioned to the engines? The average quantity of water per horse power within the boilers is about 10 superficial feet. Now the set of boilers (model) at this moment before me, and constructed upon the principle of those of the Echo, are three in number, and calculated for two 50s; the length of each 26 feet, breadth 5 feet, and height in front 6 feet, these afford eleven and seven tenths superficial feet of water per horse power. The furnaces measure 6 feet by 4 each (placed side by side), giving a total width of 12 feet, and length 18; to which add flues of 14 inches diameter, and length 36 feet for each boiler, whereby the whole caloric given out from the furnace is expended within the boilers, upon the water, and no loss sustained. Surely such a set of boilers are fully adequate to maintain steam for two engines of 50 horse power each; her old square boilers afforded no such superficies. Besides, let the vessel roll as she will, round boilers always present the same quantum of surface, whereas square boilers do not, the surface for generating steam being contracted in proportion to her laying over.

I know not that it is requisite to illustrate the "expan-

sive" principle of steam; but a very homely comparison will suffice; viz., when first a column of smoke issues from the top of a chimney, it gushes forth murky and thick; but in its progress of radiation (that is, the expansion of its particles from a given centre), it diffuses itself abroad, and progressively extends its volume, becoming every succeeding instant of time thinner; is at length distinctly transparent, in proportion as it recedes from the vent; and eventually is lost altogether in the air; and though of power sufficient, in the first instance, to produce suffocation, may notwithstanding, be safely inhaled, when so thoroughly incorporated with the common atmosphere, as to be no longer distinguishable from it. The same principle is applicable to steam; it may be admitted into the cylinder at so powerful a temperature, as, if not checked, would destroy it by the rapidity and deep plunging of the piston; but the quantity let in being limited, and when in, expanded, may be so *reduced, as to be rendered* INCAPABLE *of carrying the piston the full length of its stroke.* With such control over steam, any one will perceive how futile the objections are to the application of the expansive principle on board ship.

Although it is clear, from what has been shewn in the preceding pages that steam used expansively is conducive to economy in fuel to a very considerable extent in itself, yet there are other sources, by the judicious adop-

tion of which this saving may be still further, and very materially extended. For this purpose, our great object must be to apply such means as shall most effectually preserve steam unimpaired, from the boiler to its final destination in the cylinders; to reject every thing tending to the dispersion of heat, either through the conducting principle, or that of radiation. This can only be done by covering the sundry portions, in immediate communication with steam, with a clothing of the best non-conducting agents. Of these, wood, saw-dust, charcoal, and lead, are perhaps least expensive; and at the same time are admirably calculated to arrest the dispersion of heat in metal tubes, boilers, cylinders, &c.; the sides of which to be coated with outer plates, or boards, and the intervals filled with either of the above ingredients. Or for boilers and steam chests, they may be coated over with paint, or coal tar, thickly dusted with saw dust or charcoal, before it dries (or even with feathers) and afterwards covered with the thinnest sheet lead, such even as that used for the lining of tea chests; by this precaution, an intense heat will be maintained within, while the outer surface is unaffected. This effect I once had an opportunity of putting to the test on board H. M. S. V. Echo; the waste of caloric from the steam chest, was at one time so excessive (we worked with steam of 15 lbs pressure) that considerable danger of the wood work taking fire, was apprehended, if suffered to continue; wherefore, as a check,

the steam chest was surrounded (though very indifferently, as we could not well get at it at the time) with sheet lead; and the effect was incredible to those to whom we afterwards communicated the fact. The air-tubes, which in consequence of this redundant heat, had been especially fitted for its escape, and over which the hand could not be held for a second, became afterwards so cold that butter could not be melted on them. Such a covering, extended over, and around the boilers, and fitted close; and the steam chests clothed in like manner; as also the cylinders, would conduce to so low an expenditure of fuel, as requires ocular demonstration to be credited. Let it not be objected against this application of lead, that the heat to which it will thus be exposed, will render it liable to melt; for such is not fact. Lead will not yield to a less temperature than 540 degrees; and as steam worked at a pressure of 15lbs per square inch does not exceed 250 degrees, no apprehension of melting it, need alarm the most timid.

Again, it is known that bright metals project heat most feebly; wherefore vessels which are intended to retain heat, should be made of bright and polished materials. On this principle is the manufacture of tea and coffee pots; and, for the same reason, steam pipes for the conveyance of heat to a distance should likewise be bright in their course, though darkened when they reach their destination.

Spongy organic substances, such as silk, wool, cotton, flock, feathers, &c., are still better non-conductors than any of the afore-mentioned substances; and the finer the fibres, the less the conducting properties they possess. The theory of clothing depends upon this principle: the heat generated by the animal powers is accumulated round the body by the imperfect conductors of which clothing is composed; and women, whose garments are of the finest texture, are least susceptible of cold.

A mask, if coated with the thinnest sheet of bright tin foil, is a perfect fire screen, and so impervious to heat, that the face may encounter, without inconvenience, the blaze of a glass-house furnace.—Dr. URE.

That steam may be rarefied to too great an extent is a fact; as beyond a certain degree of temperature it is no longer steam but gas; having attained a *permanently* elastic form, and being no longer capable of condensation, is in such state useless, and inapplicable to the purposes of the steam engine, from not effecting a vacuum. The very extraordinary fact that "steam from water, when applied to burning bodies which evolve smoke, give much additional brilliancy and intensity to both the light and the heat emanating from them" has been ascertained, and many experiments made by Dr. DANA; who, on the ap-

plication of a small jet of common steam to a charcoal fire, found the brilliancy greatly increased; and that the low attenuated flame became enlarged. The experiments were varied by using different substances, such as oils, &c., with similar success.

If then such be the case, and "steam does produce an increased brightness and a more perfect combustion" when applied to flame, it is such a fact as is well worthy the attention of those experimentalists who are exercising their ingenuity in devising means for the better economising of fuel. Nor do I see any reason to doubt it; as, by decomposition the hydrogen gas becomes freed from the oxygen,* and will enter into a state of active combustion, and continue so as long as it is supported by oxygen gass; wherefore, if pit coal has the power of decomposing steam as well as charcoal, this fact may be turned to profitable account. At all events the experiment may be attempted with very little trouble, inconvenience, or expense, by simply attaching an extra tube from the steam pipe which shall lead to the furnace.

* Hydrogen, is a term applied as descriptive of the constituent of water, and is not susceptible of acidification, but is highly inflammable. Oxygen, on the other hand is the acidifying principle, from the Greek word, signifying "to produce acid." And steam being decomposed, is converted into gas; and as this gas is highly inflammable when exposed to atmospheric air it can readily be supposed to increase the brilliancy of flame so soon as it combines with it.

Mr. PERKINS, in his evidence before the Committee of the House of Commons, asserts that steam may be raised to such a height, that the superabundant caloric has been found to heat the upper surface of a boiler red hot; and to ignite coals, or other combustible matter which may be placed in contact: it is, in fact, gas, and not steam.

The accidents which have occurred from the explosion of boilers may be herein traced; for they have arisen generally, if not wholly, from *neglect in regard to keeping up the proper feed*, whereby the water has become so low within the boilers, that the steam has in consequence become supercharged with caloric. Accidents of this nature are very likely to arise if proper attention to the guages, affixed to the boilers, be not paid; as, from ashes, small coal, loose hemp, &c., the feed-pipes and pumps are extremely liable to get choaked. Should such an accident as the choaking of the pipes arise, and the steam be rarefied to a great height, were the Engineer, instead of admitting a gradual supply of fresh feed, suddenly and at once to open the safety valve, with a view of letting off the redundant steam, the chances are that this steam coming in contact with the fresh air would ignite, and set fire to the vessel; and, even if such a result did not follow, another effect would be, that this removal of the pressure of steam would cause such a rush of fresh water into the pipes as would, of itself, clear them, and force

the steam, *in a compressed form*, to the top of the boiler, where, finding no adequate vent for its sudden escape through the valve, it would become so dense as to render explosion almost inevitable. For steam, although it will pass rapidly upwards through a body of water and incorporate itself with it to the extent of making it boil, yet it will not *descend* but in very slow proportions, and so combine with water which is under it; else the danger of explosion would not be so imminent;* for although, through the *conducting* power of fluids, caloric will communicate *downwards*, yet the temperature of every stratum diminishes, in a very slow progressive ratio, from the top to the bottom.

Speaking of hot steam coming in contact with fresh air, being conducive to combustion, reminds me of a not unfrequent occurrence on board Steam Vessels, viz., "that the packing of the pistons is often found burnt." This arises from the steam escaping from the cylinder and meeting with fresh air, drawn through the glands of the cylinder cover, when not sufficiently tight; such steam

* This probably arises from the overheated steam suddenly taking up a quantity of water, and increasing thereby its pressure. Hence may be traced the probable cause of many boilers bursting. A melancholy case occurred on board the Union Steamer, of Hull, in June last; the Engineers having neglected to attend to the feed, the water in the boilers got too low; the boilers became red hot; the steam was converted into gas, and explosion ensued as the unavoidable consequence of expansion.

being highly charged with superincumbent caloric, is thus caused to ignite the packing, which is of hemp. When, therefore, an Engineer asserts that his packing is burnt, he should rather say his engine is taking air.

HORSE POWER.

It is customary, in speaking of engines, to assume that they are of such and such "horse power" this has been done with a view of establishing some data, of the relative portion of work performed by them; Messrs BOLTON and WATT estimated the horse power, at thirty three thousand pounds weight, as the capability of a horse to raise one foot high in a minute; or in other terms, that an ordinary horse was 5½ times more powerful than a man, whose power was considered by DESAGULIER to be equal to draw 6,000lbs a foot distance (in height) per minute; and which has been generally admitted from his time to the present. However, in MR. WATT's calculations, we find that at times, he calls the horse power 44,000lbs as his capability: The calculation stands thus, viz.

	lbs.	
WATT................	44,000	through one foot per minute.
DESAGULIER..........	27,500	
SMEATON	22,916	

These average 31,604lbs; but, by general consent, it has been fixed (as first estimated by WATT) at 33,000lbs; and that amount has been established as the standard.

When, therefore, we speak of the power of an engine in horses, we must do so in conjunction with the diameter of the cylinder, the length of the stroke of the piston rod within the cylinder, and the number of strokes which the rod makes up and down, in a minute; as also the effective pressure (that is, the actual resistance which it overcomes, after deducting for friction) on the piston; together with the number of feet the piston rod travels per minute. To facilitate this calculation, the following table shews the number of strokes, as also the number of feet, per minute, which the piston rod should travel conformable to the length of its stroke,

Length of Stroke in the cylinder.	Number of Strokes or revolutions per minute.	Number of feet travelled per minute up and down.
2	43	172
3	32	193
4	25	200
5	21	210
6	19	228
7	17	238
8	15	240
9	14	250

This table, I take it, is given as an *average* standard,

but subject to the force of steam at which the engines are worked, and the friction to be overcome. And the number of feet travelled through, is evidently for the *double* action, upwards and downwards; for instance, a four feet stroke, should perform 24 or 25 revolutions in a minute; then 25 multiplied by* 4 (feet stroke) is equal to 100 for the single action; and twice that number for the double action, is as above, 200 feet, the distance travelled by the piston in a minute. Then to find the horse power, as follow:

TO FIND THE HORSE POWER OF AN ENGINE.

Take the diameter of the cylinder and square it, that is, multiply the diameter into itself; multiply then the porduct by .7854 and cut off the four figures to the right; those to the left multiply by the *effective*† pressure; this

* Multiply the number of revolutions made by the length of the piston rod; suppose 6 feet and say 20 revolutions=120×2=240.

† When working at a maximum, or the greatest force of the engine, the effective pressure or force on the piston, in small power engines, after deducting for friction of the pumps, piston, beam, &c., is from 6 to 7lbs on the square inch; in engines of from 30 to 40 horse power, from 7 to 8lbs; and in larger, from 8 to 9lbs; though the actual pressure is near 16lbs; but nearly one half, or about four tenths of the power of steam is diminished by friction, (see "Vacuum Guage") and is attributable in a great measure to the

shews what the engine can raise one foot high per minute: let this be again multiplied by the number of feet travelled through per minute, you then have the weight in pounds which it can raise; divide by 33,000℔s (for horse power) the product will be the comparative horse power of the engine, proportionate to the diameter of the steam cylinder, &c.

Example. Cylinder 40 inches diameter, length of stroke 4 feet, and effective pressure 7℔s—required the corresponding horse power?

40-inch cylinder.
40
1600 Area.
.7854
1256,6400
7 ℔s effective pressure.
8792 Engine can raise one foot high per minute.
200 Feet per minute, travelled by a four feet stroke, *double action.*
33000)1758400(53 The horse power of the Engine.

error of Engineers in screwing up the various bearings too tight; and in not seeing that the piston rods &c., work in a true perpendicular line. With due precaution, the friction ought not to exceed a quarter at the utmost. To find the effective pressure, add together the vacuum, and the steam pressure at which the engine is working, deduct one half for friction, and the remainder is the effective pressure; thus, vacuum (28°) at 1℔ for every 2 inches rise of mercury, is 14℔s, load on safety valve 3℔s, equal 17℔s; deduct as above 9lbs; and we have for actual, or effective pressure, 8lbs per square inch, which is the power the engine is working at.

Or the area may be multiplied by 11, and divide by 14, instead of multiplying by .7854, and cutting off the four figures to the right: thus

$40 \times 40 = 1600 \times 11 = 17600 \div 14 = 1257 \times 7$ the effective pressure, &c.

TO INCREASE THE POWER OF THE SAME ENGINE.

(N.B. Can only be done by expansive or high-pressure steam.)

This is done by increasing the effective pressure (see "Barometer and Vacuum Guage") on the piston, by adding to the amount of vacuum shewn, the amount of *increased* steam pressure, *above* the atmosphere, at which the steam enters the cylinders. In the foregoing example the effective pressure is 7℔s; found thus; barometer shews 28° (as the rise of mercury) and, as for every 2 inches rise, we allow 1℔ pressure as the vacuum, this will give us 14℔s; to which add steam 2℔s per square inch, as the load on the safety valve=16; deduct for friction, 9℔s, gives for *effective* pressure 7℔s; and the power of the engine, that of 53 horses. But let us *increase* the weight on the safety valve, and call the steam 15℔s above atmospheric pressure, and our calculation will then stand thus, viz.

```
          40
          40
        ————
        1600   Area.
          11
       ——————
   14)17600
       ——————
        1257                         ⎧ 14 Vacuum.
          15   lbs effective pressure⎨ 15 Steam.
       ——————                        ⎪ —
       18855                         ⎪ 29
         200   Feet travelled per    ⎩ 14 Friction one half.
      ————————        minute.          —
33000)3771000(114  Horse power.        15 Effective pressure.
```

This is a practice by no means infrequent in small manufactories; where, by day, the engines are worked up to their full capability; but for the sake of safety the load is reduced for night duty, and the engines worked on low-pressure only. Should necessity render it expedient, we have the same capability on board ship at discretion, by the substitution of cylindrical boilers.

BOILERS.

The greatest attention is imperatively necessary relative to the boilers. Whilst at sea, they require to be "blown off" at regular intervals, in order to prevent any accumulation of salt, or other sediment which the water holds in solution; that is to say, where there are three boilers for

instance, one of them should undergo this process within two hours; then another, and the third within the sixth hour. Almost all waters hold in solution both carbonate and sulphate of lime, two earthy salts; of which the former (carbonate or chalk) is thrown down by bringing the water to a boiling heat; the other by evaporation. It is this combined sediment which causes the earthy crust found in steam boilers after a few days' use; the harder the water, that is, the greater the quantity of these earthy salts it contains, the more rapid is the deposition. The carbonate of lime is insoluble in water, unless carbonic acid predominates in the water; if so, it is capable of being held in solution, but so soon as the carbonic acid escapes by exposure to air it precipitates the chalk. Carbonic acid and lime, when in due proportions, form chalk; but, as above, when the carbonic acid predominates, the chalk is no sooner formed than it is again dissolved, and continued in a state of solution. And it is when in this state, attention is particularly required to free the boilers of it. The engine room is attended by six men, termed "stokers," in addition to the engineers and their apprentices; two persons, out of the six, trim the coals within the coal-boxes, so as to have supplies always at hand for the firemen; the other four relieve each other in succession, at the end of every two hours; making for each, two hours on, and four hours off, duty; the coal-trimmers are at watch and watch, for four hours each.

During the watch of each successive relief this operation of "blowing off" is performed, and one of the fires raked out, and the bars cleared of clinkers, &c.

The "blowing off," which is a matter of the greatest moment, is thus done: before opening the cocks of the blow off pipes, care must be taken that the "feed" (that is the water destined to supply the place of that to be blown off) is on the boiler;* and not only continued flowing during the whole operation, but sufficiently long after it is completed, to insure the water again attaining its proper height within the boilers; that is, midway between the two guage cocks (about two thirds full). Previous to blowing off, the water should be run up as high as the upper cock, which, if left open, will indicate when the water has attained that height. With these precautions a sufficiency of cold water will be supplied to allay the ebullition caused whilst in a boiling state, and enable the Engineer more correctly to ascertain the true guage of water, that he may not blow off too great a quantity. All being ready, the valves of the blow pipes are opened at the

* This should never be altogether off, but a constant uniform supply, in proportion to the evaporation, during the conversion of water into steam, must be kept up by regulating the valves of the feed-pipe accordingly. There is generally a ball within the boiler, filled with air, which rises and falls with the water (on the top of which it floats), and opens or shuts the cock accordingly; but it is liable to corrosion, and not to be altogether depended on.

same time, when the steam within the boiler, by its pressure on the surface of the water, forces it from thence into the blow off pipes, and through the bottom of the vessel, where it leads, carrying with it the sediment of salt, lime, &c., either still in solution, or such portions as may have precipitated to the bottom. In the performance of this duty the nicest care is requisite (see "Blow off Pipe"), and not more than six or eight inches depth of water should be suffered to escape, as the fire-flues, which lead through the middle of the boilers, and are protected so long as they are surrounded with water, might be left bare; in which case they would inevitably sustain damage of the most serious nature, from such exposure to the joint effects of fire-heat acting on the under side, and the pressure of steam on the upper. Such an exposure, if but for a few moments only, would effectually destroy the flues, and perhaps burst the boilers.

This sediment if suffered to accumulate, would not only corrode the iron, but likewise form itself into a succession of layers, which, preventing the water from insinuating itself between this calcarious substance and the iron, would soon cause the latter to be burnt through; and, if even it did not, it would effectually prevent the heat of the fire from penetrating with force sufficient to raise steam; and, in the latter case, an increased consumption of coal would follow, in the vain endeavour to keep the

steam up. Hence, a neglect of this highly important operation must lead to the progressive destruction of the boilers, and to a wasteful expenditure of fuel at the same time.

Where steam of a very superior elastic force is used, this accumulation is not so likely to take place as under the influence of low-pressure steam; because there is not the same probability of the steam going down, through a little inattention of the firemen, so low, as by the admission of atmospheric air, to generate salt.* But independent of the above attention to clearing the boilers, whilst the vessel is in the progress of her voyage, as soon after her arrival in port as the diminished heat of the boilers will admit of it, the Sub-engineer should himself go into each of them in rotation, and examine most minutely their condition, and see that every particle of sediment is carefully removed. The boilers cannot be kept too clean, whether inside or outside.

That some of my brother Officers, in command of Steam Vessels, may possibly have fallen under censure for a supposed neglect of this important duty, I can readily imagine; but that such imputation has not always

* Dr. URE found that cyrstallization is effected by "agitation" solely; and not by the chemical, nor the mechanical, effect of the surrounding air: and certainly the salts which are generated in the boilers would seem to corroborate this opinion.

been merited, I feel assured; especially those who have had the conveyance of the Mediterranean mails; and on them particularly would such imputation be most likely to fall, from the circumstance that that sea is peculiarly impregnated with this calcarious matter; and, in a greater or less degree, an accumulation of it is always found within their boilers on their return to England. But, from my own experience, I well know that Steam Vessels so employed had, during my time, too little opportunity in the various ports they touched at for a proper examination of the engines, and cleaning of the boilers; or for the discovery of any hidden defect which might have arisen on the passage. A damage might have been sustained, which only required the straining of the vessel during a gale, or in a heavy sea, to bring to light,—an occurrence of all others most desirable to be guarded against; whereas, time not admitting of an overhaul, within a day or so after departure, a leak in the boiler, which had given no previous intimation of its even probable existence, gushes forth, and half extinguishes the fire. A wasteful expenditure of fuel is the consequence, in the vain attempt to maintain steam; or perhaps the fires are raked out altogether, that the Engineers may endeavor to remedy the defect. Either way delay must ensue, and the voyage be prolonged. Moreover, the almost unceasing intensity of fire-heat, caused by the speedy renewal of the voyage ere the boilers are really cold, must necessarily tend to waste

away and destroy them; for it is an ascertained fact, that you may fire so strongly under a boiler as to drive the water off from the heated iron, and the ebullition causes an absolute vacuum between the water and the iron; in which case progressive destruction must follow. So long as water continues in contact with the metal no such accident can accrue, as the heat imparted to the metal is immediately absorbed by the bubbles of water which are converted into steam at the bottom, and rendered *latent* in them; the bubbles, as they escape at the surface, carry off with them the heat conveyed through the bottom of the boiler. This may be exemplified by holding a piece of folded *paper*, filled with water, over the flame of a candle; the water will boil, but the paper will not burn.

Hence, I trust, it will be evident that the accumulation found to be deposited at the bottom of the boilers, on the return of the Mediterranean Steam Packets, is not solely to be ascribed to neglect, or to the want of proper care in "blowing off;" but that it is really attributable to arrangements which their Commanding Officers can in no way control. Neither does the circumstance of having the Steam Vessels laid up in tiers of half dozen at the time, substantiate the imputation.

That we have had them under the hands of Dock-yard mechanics and of contractors, by numbers at the time, is

most true; but it should not be lost sight of, that those vessels were, many of them, commissioned about the same time; as also that some of them had worked their boilers to the termination of the four or five years, for which they usually last.* The constant action of the strong fires, required to raise steam, must necessarily cause them to deteriorate; for the cold atmospheric air passing into the furnace, containing the supporter of combustion, "oxygen," by which the fire burns, coming in contact with the iron, heated to a *red heat*, has the effect of oxidating that portion of the boiler so acted on, by both its own decomposition, as well as that of the water which is combined with it. The iron is thus caused to corrode, and waste away scale after scale. Under all which circumstances, there is nothing surprising that those vessels should have required repairs (more or less) at or about the

* Boilers should last three years good; then with a thorough repair, they will serve two years more; at which time they will probably require to be taken out; and the engines undergo a complete repair, whilst new boilers are being put in. But in judicious, careful hands, boilers have, with a little occasional repair, lasted 12 or 14 years in the same vessel (Comet to wit): if the vessel is kept constantly employed, it is better to keep a *little* fire constantly backed up, rather than extinguish it; for when compelled to get steam up suddenly, the effect of a *strong fire* coming in contact with *cold iron* is that of oxidating it, and flake after flake will drop off, whereas very little fire will maintain sufficient heat to obviate this; and is very different from the long continued intensity of firing spoken of above. This small quantity, moreover, will be no bar to an occasional overhaul, or to the sweeping of the flues. Neither will it be productive of increased expenditure of fuel; as, when the fires are to be first lighted, it requires a considerable quantity of wood, in the first place, and about 28 or 30 bushels of coals after, before the steam will be up; leaving out of the question, the time required.

same time. But many of them are very unnecessarily kept in hand, as I shall have occasion, by and bye, to notice. If boilers and engines must be furnished by *contract*, that contract should include "keeping them in repair at the charge of the contractor for a given time—say three years." But in proof that unnecessary detention takes place in the Dock-yard, let me ask how it was that the *Firefly*, during the whole three years she was commanded by Lieut. BALDOCK, never missed a single trip to the Mediterranean? Why solely because *she* was never, during the whole of that period, once sent to Woolwich, but was always repaired, *under his own inspection*, by mechanics at Falmouth—a privilege granted to no other officer. He had an interest in expedition—so would the contractors have under the above stipulation; as they would not willingly be paying men for doing next to nothing.

Without, however, meaning to question the make of the boilers, or the *material* of which I have sometimes seen them composed, I cannot but think that until Government shall form an establishment of its own at one of the Royal Dock-yards, for the *manufacture and the repair* of the boilers of H. M. S. Vessels, and under the superintendence of two or three efficient *Naval* Officers, holding adequate rank for such important appointments, combined with a knowledge of steam apparatus, commensurate with the

duties they will have to perform, and which must extend to arrangements relative to fuel, as well (in all which we are now lamentably deficient) I fear there will always be disappointment, more or less, at those times when Steam Vessels may be required for service. As at present managed, Steamers very frequently undergo considerable repairs in their machinery, which practical *naval* men would at once see to be unnecessary; and by which expenses are incurred and time lost. This does not occur among merchant Steamers. We yet hope to see boilers arranged in classes of 50^s, 80^s, and 120^s, and not that promiscuous nondescript tribe dispersed at present throughout the Royal Navy; and which furnishes excuses for contractors not having sets at hand to replace those that require great repairs.

But to return to the management of the boilers; for I cannot too strenuously impress on the Commanding Officer, that this is the fountain head from whence all benefit is derived. The engine may be damaged, but the supply of spare gear, with which the vessel is furnished, will enable him to rectify those injuries most likely to occur therein; all its parts, save a few valves, are within view; not so the boilers; the fronts of them alone are visible. It is therefore, of the greatest importance that the moment his primary duties of waiting on the Commanding Officer, &c., admit of his attendance in the

engine room, and that the boilers are sufficiently cool, he should see the Sub-Engineer enter at the man-holes, and proceed on the inspection internally, as well as externally; and receive his report on the completion thereof. And if there be a weakness discovered in the iron, and it appear judicious to guard against any ulterior consequences, which may be likely to accrue, better at once proceed to remedy the defect, by attaching a plate of iron, and secure it with screw bolts, washers, nuts, &c., even though a little delay should arise; for one hour's detention in port, beyond the stipulated forty-eight, for this service, may save even days of delay on the voyage, should such repair become imperative whilst at sea, even under the favorable circumstances of fair wind and fine weather; but should it prove tempestuous, an event by far the more probable, as it is the straining which generally brings such damage to light, the requisite repairs would be difficult, if not impracticable. It is of equal import, that the incrustation already adverted to, should be pricked away, and removed, as effectually as circumstances will admit. This sediment is more peculiar to the waters of the Mediterranean and the Tropics, than to the sea water of our own Channel, where salt only is likely to accumulate; whereas the former deposits chalk, common, and glauber salts.

If when running up a fresh water river, after coming

from sea, the boilers are found to emit water, it does not follow that a leak has taken place; as this arises from the admission of *fresh* water as the feed, which coming in contact with the salt resting on the bottom (the deposit) dissolves it, and oozes through the joinings of the plates at the riveting; it will soon take up.

FUEL.

Under this head various substances have been resorted to for the generating of steam; but we will confine our views to those materials which are in common use. In this country we are blessed with an abundance of coal, but of various qualities certainly; some more fitted for our purposes than others. In America, where steaming is carried to the greatest extent, wood is the chief, if not the only article of consumption; but as their navigation is confined to their own rivers and lakes, the supplies are not difficult of attainment, else the bulkiness of that species of fuel would prove an insuperable bar to long voyages. Charcoal I believe, has been attempted; but this I do not imagine to be capable of raising steam with advantage; as, in the process of charring, the gaseous properties, originally belonging to it as wood, must be lost; and it is absolutely necessary that *flame* should circulate within the flues; whatever caloric it may retain, as char-

coal is greatly deteriorated. Coke is in great consumption for rail-road engines; but for our purposes on ship board, is liable to the same objection as charcoal; though, as it gives out an *intense heat,* a bed of fire from it, spread over the furnace-bars, would effectually ignite all *small coal, coal dust, and smoke,* which should pass from the mouth of the furnace into the flues, and convert them into *flame* during their passage; which, circulating through the boilers, would impart its caloric to the water; and cause a considerable saving of fuel, by thus converting so much, otherwise *unburnt* materials, which now passes off as "black smoke."

To produce equal heat, ¾cwt. of Newcastle coal has been found equal to 1cwt. of Glasgow coal, and to 2½cwt. of wood. The Llanelly, called Langenock coals; and the Swansea, or Graiola coals, are by far the best sorts for raising steam, combined with economy. The Hugh Lindsay, Steamer, from Suez to Bombay, found, on comparison, that 12cwt. of the above Welch coals, went as far as 15cwt. of Newcastle. Many experimentalists affirm, that the difference is, as 11cwt. to 16cwt. of Newcastle.

In using wood, the lime tree wood gives out more heat than the pine; beech less than either; and the oak is inferior to all three. Elm is considered the next in quality;

but a good deal depends on the proper arrangement of it in the furnace; as it requires judicious packing; and on this rests considerably its economic use. Its effect in producing heat depends mainly on its state of dryness; that of green wood, unseasoned, is considerably less than that of well dried timber; as the former contains about a third of its weight of water

With regard to the consumption of fuel, much depends on the nature, the form, and the manner of fixing or setting the boilers; as well as the draught of the flues; and attention to the state of the steam guage, that it does not fluctuate too much, either by having a wasteful redundancy of steam flying away at one time, or an inadequate supply for the cylinders at another; as also to the feeding of the fires. On the low-pressure system, the average* consumption of a shore engine was estimated as under, viz.,

Coals from 9 to 12lbs per hour, for each horse power.
Wood.... 25 to 30lbs per hour, for each horse power.

But on the expansive principle, the following memo-

* The river steamers of 160 horse power (two 80s) average from 17 to 18cwt. per hour, which is about the same as the above estimate; making a consumption of about 24 bushels an hour; which is 3 bushels short of a ton; but for the waste on coal dust, and (for the want of sifting) cinders, may be calculated at one ton an hour.

randum exhibits the consumption of coals on three several mines. The engines varying in diameter of their cylinders, the length of stroke, steam pressure, or load on the safety valves, and work done.

Mines.	Diameter of the Cylinder	S okes per Minute.	Length of Stroke in the Cylinder	Length of Stroke in the Pumps.	Steam pressure per square inch.	Load lifted at each stroke of the Pumps.	Coals consumed in 24 hours
	inches,		Feet.	Feet.	lbs.	lbs.	Bushels.
W. Damsel	53	3	8	7	30	30,000	27
Poldice ..	90½	6	10	8	27	90,000	96
Job's	90	7	9..6	7..6	29	76,855	88

There can be no mistake in respect to the coals, because they are always measured out for the purpose of not only ascertaining the expense, in a relative proportion to the work done, but moreover to obtain the drawback on the quantity consumed, which is allowed at the Custom House.

The foregoing is indeed a small consumption for such powerful engines,* and such as we must not expect to realize on board steam vessels; but as heretofore observed, engines worked on shore, possess advantages unattainable on ship board; as independent of the benefits arising from the manner of setting the boilers in mason work, the

* The above are *single* acting engines, and from 200 to 250 horse power, which at the average of ninety bushels of coals in twenty-four hours, will not exceed half a bushel per horse power, for a whole day.

apartments are better adapted to the machinery; and the cylinders, steam pipe, &c., being clothed with saw-dust, planking, or other materials, the steam is preserved unimpaired from the boiler to the cylinder. From such favorable circumstances, the fires are kept steady, at about six or eight inches from the bottom of the boilers; consequently, the coal which from time to time is thrown on, having a solid bed of fire to settle on, renders it of little importance whether such fuel be small or rubly; as no waste can accrue from falling through the bars; not even the very coal dust itself can escape being consumed, and those few cinders which do fall through, can be, and are collected, and mingled with small coal to be burnt over again. Hence another source of economy on shore, which is not very easy of attainment on board ship;—though I have done so on one or two occasions, in order to try the efficacy of the plan—and the success was such, as to induce me to say without hesitation, that every steam vessel whose stoke-hole will admit of it, should have a wire screen sifter attached, which, like the hopper of a flour mill, may be made to work by the action of the engine. Furthermore, on shore the same room which contains the machinery is capacious, lofty, and airy, without being subject to strong currents of air; whereas on board ship, the engine room is, from necessity, contracted, and at a temperature varying from 65 to 75 and 105 degrees; and instead of an uniformly steady fire,

every change of weather causes a corresponding change in the engine room. And from the rolling or pitching of the vessel, coupled with the constant raking of the fires, and opening the fire doors, which with us is necessary, in order to clear away the clinkers for the admission of air to maintain the draught, the waste of fuel, or rather of coal dust, becomes immensely great. For this small stuff falling through the fire-bars, becomes mingled with the ashes; and as we have no space for raking it about in the stoke-hole, to select the larger portions, it is thrown overboard under the name of ashes. The intensity of heat, and confined space precludes the possibility of having recourse to this economical expedient. Again, the consumption of fuel is increased whenever sails are set; the increased draught, from the wind passing from the sails down into the engine room, rushes into the furnace like a current of air from a bellows; and whenever the fire-doors are opened, this cold air refrigerates both the furnace and the fire, and wastes fuel.

On mines, or in manufactories, the case is different; but on ship board, supplied as vessels are, this waste of small coal, I have no hesitation in saying, amounts to near a third of the quantity of fuel (for coal it is not) sent on board. Vast quantities of this fine stuff, when thrown into the furnace, is forced up the chimney by the draught from the furnace; a fact which every Commanding Officer

of a steam vessel will soon discover, especially if he be any way particular in keeping his decks white. The only way to avoid this waste, is to have the coals, before they are issued to the vessel, screened over a riddle of at the very least two inch mesh; for after all, there will be a considerable quantity of small stuff, arising from the act of starting the coals into the coal-boxes.

But whatever species of fuel is used, whether wood or coals, it should be as dry as possible,* otherwise a consisiderable portion of the heat will be lost in converting the water, contained in wet fuel, into vapour. It is therefore essential that the man-holes, over the coal-boxes, should be fitted water tight, to prevent the rain, or sea water, from passing down from the deck (see article "Trap-hatches").

It being a matter of the greatest moment that Steam Vessels should be supplied with coals of a quality best adapted to the raising of steam upon the most economic principles, I shall avail myself of the experiments of Messrs. ACCUM, TREDGOLD, and others, to point out a

* When using coal-dust, however, it should be moderately damped, in order to make the particles adhere together; but the most effectual mode of using coal-dust is to mix in with it coal-tar, so as to make it up into balls or bricks; and if fuel should run scarce, a further economy will be found in adding about one-third ashes, one-third coal-dust, and one-third coal-tar, together. Common tar, liquified, will answer in the absence of coal-tar.

few varieties which are calculated to attain this end. That there is a very considerable difference between the qualities of coals, every one knows; but, hitherto, the qualities of the sundry varieties have been studied more in regard to the production of gas, than with a view to economy in consumption on ship board.

Newcastle coals may be classed under two heads; the one species, when heated, breaks into small pieces and cakes into a solid mass, which requires to be frequently stirred, in order to admit the draught through it. Of this species, the Tanfield Moor burns slowly, cakes very hard, and gives out a strong and long-continued heat; consequently it is well adapted for the uses of furnaces and forges. The Wallsend, another species, on the contrary, burns away quickly, and does not cake hard, but exhibits a brilliant and pleasing fire; hence this is preferable for parlour fires, and the like. Caking coals give out a greater quantity of heat than those which do not cake; and if properly attended to, they burn a long time; wherefore, when they can be procured at reasonable prices, they are to be preferred.

From the experiments of Mr. Watt, it appears that a bushel of Newcastle coals, which, on the average weighs 84lbs, will convert from 8 to 12 cubic feet of water into steam, from the mean temperature of 52 degrees. Splint

coal, which is a hard and slaty kind of coal, obtained from Scotland, and also from several English and Welsh pits, is considered equally valuable, especially for steam engines, as the Newcastle; but it requires a greater heat to make it kindle, than the caking coals do. It, moreover, does not produce so much flame or so much smoke; and as it does not cake together, it is not requisite to rake it about so frequently.

Another species of coal is the Staffordshire Cherry coal, which is soft, and readily catches fire; it gives out much heat, but burns away more rapidly than either of the foregoing, leaving a white ash behind. This, like the splint coal, does not melt and cake, consequently does not require much stirring.

Mr. Accum, whose experiments on coals were, I believe, chiefly made with a view of ascertaining which quality was best adapted for the production of gas, divides coals into three classes; viz:—

1st, Cannel and Lancashire coals, or such as are composed chiefly of bitumen. This class gives out a bright and yellowish white blaze; does not clinker or produce cinders, but is reduced to white ashes. Besides Cannel and Lancashire coal, most of the varieties of Scotch belong to it. This species we have found peculiarly

desirable, as it generates steam quickly, never burns the bars (the effect of sulphur), nor does it clinker. It, moreover, produces very little dust in the flues or engine-room, or coal dust in the boxes, whereby the brasses of the engine so frequently suffer. The consumption, however, was found to be 3 bushels an hour (under boilers for two 50s on board the Meteor), more than that of Welch coal. As a set off to which, the speed of the vessel increased half a knot, from 6½ with Welsh, to 7 knots with Scotch coal; to say nothing of the wear of the brasses (by the sand dust, or grit, from the Welsh coal), which were as bad as though they had been sand ground intentionally; and after 4 or 5 days run, the flues became so choaked between coal dust and soot together, from the latter coal, that it became imperative to sweep them, the draught being nearly stopped; and instead of a few buckets of dirt, which is the result of Scotch coal, nearly a waggon load was extracted. The oil and grease cups likewise catch a portion of this grit, and injure the rods which work within them.

2nd, Newcastle coal; a strong burning coal, which contains less bitumen, but more charcoal; does not burn so bright as the above, but with a flame of a yellowish tinge. After laying on the fire for some time, these coals melt and cake at the top, so as to obstruct the current of air passing up through them; whereby, if not continually stirred and

broken, the under part would be consumed without throw ing out the requisite heat for boiling; and the fire would speedily become extinguished. Coals of this description produce less ashes, but hard grey cinders, which may be mixed with fresh coal, and burnt over again with advantage.

3rd, Welsh, Kilkenny, and Stone Coal; these contain very little bitumen, and are chiefly composed of charcoal, combined with different earths. Such coal requires a very high temperature to cause it even to ignite; nor will it burn until it is wholly ignited.

The species of coals, found in Wales, and known as "Stone coal," but likewise called "Anthrocite," is said to abound in America. This coal requires a very great heat to make it burn, and must be maintained by a sharp, quick draught; it will then resemble molten metal; gives out an intense heat, unaccompanied with smoke, and is admirably adapted for malting. In the smelting of iron also, it has not only been found very superior to all other coals in point of economy, but the metal itself to be greatly improved by its quality. This coal, however, is inapplicable to low-pressure boilers; as from the intensity of heat, which it throws out, the particles of water are made to fly off from the iron on which it should rest, and the bottom of the boiler is thereby exposed to the fire,

which speedily destroys it; the elastic power of low-pressure being inadequate to keeping the water down, and in contact with the metal; whereas, a pressure of 40 or 50lbs per square inch, acting upon the surface of the water within the boiler, will have the power of pressing the water down, and prevent its being driven off from the iron, by the intensity of caloric. In America, where high-pressure steam only is used, it is said to be getting much in use.

The following results shew the quantity of gas which one chaldron of coals, of the several qualities of each class, will produce: viz.—

CLASSIFICATION.

FIRST CLASS COALS.	*cubic feet.*
Scotch Cannel Coal	19,890
Lancashire Wigan	19,608
Yorkshire, Wakefield Cannel	18,860
Newcastle, 1st quality	16,920
2nd	16,120
3rd	15,876
4th	15,112
Gloucestershire, High Delph	16,584
2nd Low Delph	12,852
3rd Middle Delph	12,096

		cubic feet.
Staffordshire,	1st quality....	10,866
	2nd	10,223
	3rd	9,796
	4th	9,748

SECOND CLASS COALS.

1st variety,	Bewick and Crastor's Wallsend	16,897
2nd	Russel's Wallsend	16,876
3rd	Heaton Main....	15,876
4th	Kellingworth Main	15,312
5th	Benton Main	14,812
6th	Wear's Wallsend	14,112
7th	Brown's Wallsend	13,600
8th	Burdon Main	13,600
9th	Manor Main	12,548
10th	Bleyth	12,026
11th	Eden Main	9,600
12th	Primrose Main	8,348

THIRD CLASS COALS.

1st variety,	Trawsaran	2,116
2nd	Ditto	1,656
3rd	Blenew	1,416
4th	Gwendrath	1,486
5th	Ditto	1,292
6th	Rhos	1,272

And, according to TREDGOLD, to convert one cubic foot of water into steam, requires of Coke 7.70lbs

Coke	....	7.70lbs
Newcastle Coal	....	8.40
Splint Coal	....	8.40
Charcoal	....	10.60
Staffordshire Cherry Coal		11.20
Wood, dry Pine	....	19.25
Beech	....	27.00
Oak	....	30.00

These experiments demonstrate the comparative merits of each species of fuel,—evidently in favour of coke; and that of coals, about one-third quantity less than of wood, is equivalent to the latter. Swansea and Newcastle coals are considered to be nearly equal, the preference, however, in favour of Graiola; one bushel of either will convert from 8 to 12 cubic feet of water into steam. The Llanelly or Langenoc, another Welsh coal, is also on a par with the above. Of the Scotch coals, the Wylam Main, whilst to be had, was for *short* voyages very desirable; as also the Forden Main and Eden Main, which are nearly as good; they stow well, burn free, are rubbly, and not dusty, consequently admit a free current of air to pass up through them, and they deposit very little ashes. But for distant voyages they do not answer; especially on board the small class steam vessels, as they burn out too quick to admit of stowing a sufficiency; the consumption being

found to average 3 bushels an hour more than the Graiola, or the Langenoc coals. Next to these we have found the Brindowey, another Welch coal; Sir Philip DURHAM'S coals; the Halbeath, a coal from Inverkeithing; to be among the best. All inferior coals require a strong draught, and more time, to produce the same effects; the consumption must of course be greater in consequence.

N. B. A ton of coals is put on board a collier in the

Tyne for	10*s.*	3*d.*
Freight to London for ditto	10	3
Port charges in London on ditto ..	2	9
Delivered wholesale to the dealer in London, per ton, for ..	£1 3	3

Whatever increase of price the consumer pays, varies every market day, which is Monday, Wednesday, and Friday; and depends not on the first cost, as the price at the collieries very rarely varies, but on the supply and the demand. The same prices (from 9 to 12 shillings) are the average charges at most collieries, North or South country, and the differences to the consumer vary according to the port of delivery.

In regard to the *weight* of coals, 84lbs may be taken as the average weight of a bushel; thus—

Newport	....	90lbs.
Newcastle, best	....	88
Wallsend	....	80
Wylam	....	77
		4)335
	Average	84

In studying the economy of fuel, let it be remembered that in regard to low-pressure steam, the larger the boilers the greater the saving of coal; as they do not require to have the fires forced in case of temporary neglect of the firemen, or of having indifferent coals; because large boilers will hold in reserve, or ought to do so, more or less surplus steam, beyond the actual demand for the cylinders; beside which, the *proportionate* consumption of fuel diminishes as the dimensions and power of the engines and boilers are increased; consequently a large engine can be worked at a less comparative expense than a small one.

With respect to feeding the fires too, the greatest care is required that the steam should be maintained at an uniform temperature; or attempts at economy are vain. By consulting the guage, affixed to the steam jacket of the cylinder, this may be easily done; and it is this uniformity in the steam guage which constitutes a good

stoker; the difference between the firemen attendant upon the furnaces in rotation, is palpably perceptible without moving off deck; and it is upon the judicious management of the fires, that greatly depends the economy of fuel. This attaches to our own personal attention; and herein the Commanding Officer should be on the alert. An occasional glance at the top of the waste steam pipe will inform him how things are going on in the engine room, by the state of the steam. A gentle lambent vapour should be playing about the upper end of the pipe; but not running away to waste, in absolute clouds; when there is more steam generated than is required, or which is the same thing, when there is a greater quantity of steam within the boilers (or steam chest) than the safety valves are calculated to repress, those valves lift, and the surplus steam is immediately seen floating away in volumes as ample as the smoke does from the chimney; the fires are then raging with unnecessary fierceness, and the coals consequently, burning to extravagant waste; this leads to throwing open the fire-doors, which renders the matter worse, for the cold air is then admitted to the heated iron of the boilers, *red hot*, over the furnaces, and oxidation ensues, to the deterioration of the boilers. On the other hand, the fires must not be suffered to deaden, or get too low, as the required supply of steam must in such case fail; and extravagance is again incurred in regard to the consumption of fuel; as, that quantity of coal which at the

time, is in the furnace, being too limited to raise steam, is burning to no profitable purpose; and when the discovery is made that the fires are too low, on goes a heap of fresh coals at once, which deadens what little fire was then existing, for a time, until such fresh coal shall have become heated; and before it shall have kindled into flame, a great portion of it must smoulder, and become smoke or soot only, and escape without combustion, up the funnel, before the mass of it shall have attained the character of a steady fire, and the necessary temperature regained. The quantity of smoke and soot, so escaping, is literally unconsumed fuel; and although smoke and soot will in all probability escape, more or less, yet to arrest them in their way towards the funnel, constitutes the art of a fireman; for, as it is necessary that *flame* should circulate through the flues, in large volumes, so the fireman should be careful to preserve a strong bed of embers, glowing bright, at the further end of the furnaces, near the bridge, in order that the smoke from fresh coals, when placed at the mouth of the furnace, shall pass over it, in its progress towards the flues, and becoming ignited, enter them as *flame*. To effect this, the fires should be constantly supplied, at short intervals, with small portions of coal at the time, placed just within the fire-doors; by which a constant flame and clear fire will be maintained, and which is the true principle of economy, in regard to the duties of the firemen; and which it is also the duty of the

Commanding Officer to enforce; for neither the form nor the setting of the boilers, nor the length of the funnel, depend upon him; though they contribute much to the desired end; over them, however, he can exercise no control. But there are other means of attaining the same end, though only to be had recourse to on occasions of expediency. One great leading feature in steaming is, "the greater the speed, the greater the *proportionate* consumption of coals per hour." That is to say, to accelerate speed, it will require *a much greater proportionate* quantity of coals to obtain the last mile additional, than the previous one; the reason is obvious; for the greater the speed, the more the proportionate *resistance,* and consequently the greater the consumption of fuel to overcome that increased resistance. If this requires demonstration, let any one set off with a smart pace, and go over a given quantity of ground; after which, let him increase his pace, and get into a run, he will soon feel the truth of the above axiom, by the increased resistance he will find opposed to his progress.

Upon this maxim may be founded a system of economy, to be adopted in cases when fuel may be likely to run short, or be difficult to replenish. Thus, for instance, we will suppose a distance of 1500 miles as the voyage to be performed; this, at seven knots an hour, would take nine days to do it in, requiring an expenditure of ten bushels

per hour, on an average, of coals, or 2160 bushels; but wishing to perform the voyage in seven days, I find I must average nine knots; to do which will require an increase of coals to fourteen bushels an hour, amounting to 2352 bushels on arrival. Consequently to gain two days in time, will require 192 bushels, or 5½ chaldrons, more than by keeping the vessel at seven knots; but which, at this *diminished* speed, would be saved.

The usual consumption of coals, on board Steam Vessels, after getting the steam up in the first instance (and for which about 28 or 30 bushels are generally allowed) will be found to average from 9 to 12 bushels an hour, for the small class vessels from sixty to one hundred horse power; the larger classes, from 160 to 200 horse power, will consume between 18 and 24 bushels in the same time; but considerable differences (always supposing the best quality coals to be used) will arise in the same class vessels, according to the position of the funnel, consequently of the draught it maintains. As a general rule for determining the position of the funnel, we may say that "where the fire-heat ceases to maintain the temperature required to produce steam of the proposed pressure, that is the spot where the chimney should be placed." If, for instance, the intended pressure of the safety valve over the atmospheric air is to be 15lbs per square inch, that will require two atmospheres, or about 250 degrees of heat; then, if at

the distance of once and a half the length of the boiler (that is, the flue, within the boiler, after reaching from the furnace to the extreme length of the boiler, and bends back again to half the same length, before it turns upwards to pass the smoke out) the heat amounts to 250 or 260 degrees, there fix the chimney, having then attained the full amount of fire-heat; short of this is unprofitable, and you waste fuel by passing the smoke and soot off before it is entirely consumed. If only one temperature be required, as for low-power boilers, this will require a temperature of about 212 or 215 degrees only, and place the chimney accordingly. But if these distances be exceeded, an advantage will be gained by the retention of what residue of heat may still remain in the current passing up to the funnel; and this will be expended on the water surrounding the flue, and none of it escape into the open air. This constant waste of caloric is palpable, as we often see the flame circulating over the chimney tops of Steam Vessels; and when this occurs there is evidently so much heat unnecessarily lost; had it been exhausted on the water within the boilers, a less quantity of coals would have sufficed for the furnaces. To obviate this waste of caloric then, it is only necessary to lengthen the flues (that is, multiplying their number) within the boilers. In doing this, however, the *fire* should be uppermost, allowing the under flues to take such surplus caloric; because as the water is there coldest (being neither at the top with

steam nor at the bottom near the furnace), so the last passage of fire-heat will contain sufficient caloric to heat it a little; whereas, if placed above the *actual* fire-flue, it will to a certain extent, cool the heated steam rising from the hotter flues below. This flame may, however, arise from the gas escaping out of the soot, and igniting on mixing with fresh air.

Mr. Perkins, to whose scientific acquirements we are indebted for many improvements in the application of steam, has experimentally demonstrated that this superabundant caloric may be turned to profitable account *without* extending the flues, as proposed above; but by a contrivance within the boiler, which compels the water to take up every particle of heat; insomuch, indeed, as that those parts of the boiler which are in immediate contact with the fire do most good the stronger the fire is. He took for his basis the well known principle that "as the bubbles ascend from the bottom* of the boiler, so there must be a downward current to make good what ascends;" as also "that nothing is more capricious than the ascent of those bubbles, and the appearance of the top of the boiling water;" and, furthermore, that "the hotter the

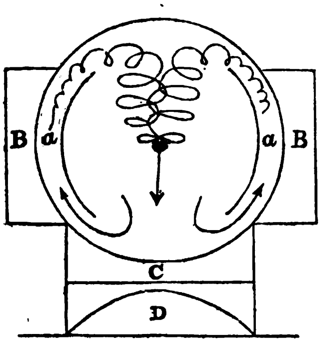
* The process of water boiling, may be exemplified by immersing a phial of water in a tumbler or bason of boiling water; when two currents will be distinctly seen; one *upwards* at the sides nearest to the source of heat; the other *downwards*, in the centre, or furthest off from it.

sides of the boiler, the more the water flies off, and is kept away from the surface of the metal."

It thence occurred to him, that if he could keep the water always in contact with the side, the heat, as it came from the fire, must be carried away by it. Availing himself of the current which the ascent of the steam through the water might create, he made a lining to his boiler, about three inches from its side, as high as the fire goes, with the whole space, or mouth, open at the top and bottom; within this lining the whole quantity of steam-bubbles rise, and as fast as they ascend, fresh supplies of water follow from below, through the opening, to fill their place, and which carry off the fresh heat as fast as it comes; whilst the water in the middle of the boiler goes down to supply the place of that carried up between the lining and sides, thereby restoring the equilibrium.

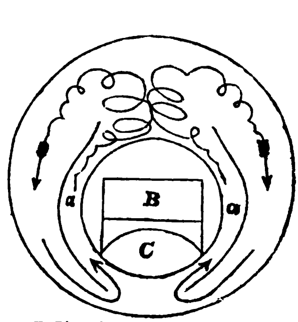
PERKIN'S BOILERS.

Flues outside of the Boiler.



B Flue. C Fire place. D Ash pit.

Flues in the middle of the Boiler.



B Fire place. C Ash pit.

a Denotes the lining of thin sheet iron to keep the up-current of water always against the metal, where the fire comes; so that the iron never can get above a certain temperature. And, as the current is always acting, salt cannot accumulate and form a lodgement. The arrows shew the course of the water.

It has been found that by this contrivance a *fifth* part of the customary consumption of fuel has been saved in *open* boilers; there can then be no doubt but that the advantages would be very much greater in close boilers. The boilers, moreover, are always safe; for, as the metal cannot get red hot, they cannot blow up; and they have been worked on this plan as high as 350℔s pressure per square inch. So "pressure" is nothing in regard to danger; and as it effects the machinery of the engines, it has already been observed that if steam be employed on the expansive principle, there need be no apprehension as to its racking the engines.

DRAUGHT OF THE FURNACE.

The draught arises from, and is in proportion to, the velocity with which the current of air enters the furnace, passing *through the fire* (the fire doors being closed) into the flues; and from thence upwards into the funnel. If it

be too quick, the consumption of fuel must, of necessity, be proportionably rapid; if, on the other hand, it is not sufficiently so for the required degree of fire-heat, it will be difficult, with any supply of coals, to maintain steam adequate to the work to be done.* So that either extreme is attended with extravagance in the expenditure of fuel: for in the former case, there is not only too rapid a combustion of the material, but the over preponderating current of air up the chimney, like a common whirlpool, carries up with it all the lighter particles of small coals, which it can support before they become ignited; in the latter case the deficiency of a proper draught causes a smouldering only of fuel; which passes off in a state of half burnt material, under the names of soot and smoke. Wherefore, in order to apportion the proper supply of fresh air, the length of the funnel should be in a relative ratio to the superfices of fire to be kept up. This adjustment is not so difficult to attain on shore as on ship board, where the natural draught is accelerated, in a greater or a less degree, according to the state of the weather; making and shortening sail; introducing windsails into the engine room, &c.; all which is ever varying.

* When the draught is found to be too quick, take the earliest opportunity of having the fire-bars placed closer to each other; if too slow, further apart; the best average distance, from bar to bar, is about an inch and a half. But dampers should be placed within the chimney funnels, to be regulated by hand, and opened or closed at the discretion of the Engineers, so as to diminish, or to increase, the draught according to circumstances; for the current of air, passing down into the engine room, varies continually, as the vessel is going head to wind, or the contrary; whether she is under canvas, or not, &c.

The draught of the furnace is aided by what is termed the "bridge;" which is an elevation, somewhat sharpened to an angle of about 45 degrees, placed at the further extremity of the furnace; and is, in fact, not only a termination, or back to it, but forms a contraction from the furnace into the mouth of the flue, whereby the draught is accelerated. From the exposure of the surface of this bridge to the intense rays of heat, the iron was discovered to wear fast; and it is now frequently faced with fire-bricks.

The foregoing definition of the action of atmospheric air on the fire, may be brought more immediately to view, by reference to the fireside comforts of our own chimney corner. In the humble dwellings of the less opulent, where economy is of first-rate consideration, the contracted fire-place, of eighteen inches width, induces a draught which renders a damper indispensible; or else the chimney is narrowed to a small compass at the bottom, and widens as it ascends upwards, forming an angle of about 15 degrees, for about two or three feet in height from the fire-grate, before the flue, or chimney, assumes its general square form. A fire-flue so constructed, though divested of elegance in appearance, affords the greatest portion of heat at the least expense of fuel; as the draught is thus made to pass through the *body* of fire; whereas, the spacious aperture of the fire-grate receptacles of the wealthy,

instead of inducing that current of air *through the body* of fire, which is so essential to combustion, admits the atmospheric air to spread *over the top of, and around,* the fire, and causes refrigeration; instead of quick combustion; and the consequence naturally results, that the consumption, or rather the expenditure, of fuel is great in proportion to the space exposed to the passage of atmospheric air *over,* instead of *through,* the fire; and that without contributing any great degree of warmth.* But to return to the flues of a boiler; it is known that a steady uninterrupted course or current of flame, only communicates its heat where it comes in contact at the edges; and that the centre of that current does not contribute, unless it be obstructed in its passage, and thereby forced into contact. Now, were the flues of sufficient diameter to admit the practice, hollow tubes placed transversely across, and open on each side the flue (to admit the water to circulate through them) would have this effect of obstructing the straightforward quiescent current of caloric, and by the deflection, add very considerably to the actual fire-surface, and increase the temperature.

Having thus endeavored to shew the principles on

* The waste of heat from such a fire place, in a room, is about nine tenths; only one-tenth contributing warmth; as the cold current of air from every corner of the room checks the radiation, and damps the fire in the grate. The nearer the throat of the chimney is to the fire, the stronger the draught, and the less liability to smoking; but this induces a quick draught, and if not regulated by a damper a quick consumption of coals; but then you obtain the full benefit of heat from them.

which the economy of fuel mainly depends, let us next proceed to "Velocity;" which comprises the various essential points belonging to Steam Vessels.

VELOCITY.

Prior to entering upon this portion of my subject, it will be as well to observe, that with regard to Steam Vessels very erroneous notions are entertained; and the first great and still prevailing error, is their "build;" that is, their form: the second, the consumption of fuel: and thirdly, the proportion of horse power to tonnage.

That theory is a beautiful ground-work for science there can be no doubt; but science should soar above the shackles of theory; it is this tyranny, however, which has impeded improvements in Steam Navigation; and ship-builders will adhere to particular forms of construction because they have been habituated to them, and will not depart therefrom, although the propelling power, by which they are to be operated on, is totally different.

First, then—It has been assumed that because the "Admiralty Steamers have averaged only 7¼ knots an hour on 51 voyages, no other Steam Vessels can be expected to exceed that velocity." In regard to speed, the

Admiralty vessels, from whose performances this conclusion has been deduced, were of the very worst class of vessel used as "Steamers;" and were those introduced in the early stages of steam navigation; vessels built on the scantling of ten-gun brigs, with an addition of ten feet to their length; drawing a great depth of water, for their size and intention (13 to 14 feet), and stowing very little coals (about 35 tons, on an average, or four days supply); consequently, when proceeding on a voyage which extended beyond the precincts of our own shores, they were burthened with, at the least, four days more fuel, *on their decks* (top hamper), in addition to that which already filled up their coal-boxes below. Furthermore, these vessels were designed to *sail* as well as to steam; and were rigged accordingly (some as brigs; and I believe all of them, originally), carrying heavy weights aloft. Can it then be matter of surprise that *speed* was not to be obtained in such craft, as *Steam* Vessels; take their paddles away, and faster vessels under canvas alone, will scarcely be found; but even *one horse power* for every *two tons* of measurement, could not drive such vessels through a rough sea, at a much greater average than 3 knots. This was too evident to escape notice; and to remedy it, another class was substituted, of "sylph like form," it is true, but perfect coffins; to wit, Phœnix, Dee, Salamander, and Co., and consequently most inadequate *sea* boats; beautiful to look at; taper waisted as a wasp; and as sharp in the

bow as the bill of a snipe; admirably calculated for running over a lake, provided the blast does not excite the rage of the billows. Here were exemplified the trammels of theory;* for these vessels were constructed by different builders; and the only exception to this tribe, is the Medea. As for the Rhadamanthus, she forms a class of her own; and well worthy of imitation. Well, the above class soon betrayed their inefficiency; and a third description of Steam Vessel, also appertaining to the Admiralty, was next introduced; but bearing a strong similitude to the middle production; though, from their increased breadth of beam, evidently different, and far more *promising;* but abounding in the same defects, of sharp, lean, bows, which marked the inefficiency of those they were intended to supplant. The first class, then, failed in point of velocity; the second, have miraculously escaped the fate of the Erin (Phœnix twice on the north coast of Spain, and the Dee on the south coast of Ireland); and the third class are now upon trial, and are variously reported upon; but which, without question, are but very little better as *sea* boats, than the *intermediates*; being so lean forward,

* Between theory and practice there is, at times, a wide distinction, as in this instance; the sharp bow, which is evidently well adapted for *dividing* the water with facility, and apparently with but little resistance, would appear most appropriate; whereas the bold bow has been proved in practice to afford far more facility for the *escape* of the water which it displaces, and thence contributes to *greater* velocity; independent of which the bold bow eases the vessel in pitching, and helps her in lifting again; nor can she plunge so deep.

as to bury themselves, without even the plea of being overpowered by their machinery; as they average from 2½ to 3 tons per horse power. There is, however, a class of Steam Vessels, belonging to Government, which reflect credit on their builders, viz. Lightning, Comet, and Rhadamanthus; perhaps the Medea may be included; *but not one of them has steam power sufficient.*

The long sharp bow of a vessel passing through the water, or the taper end of a spar, may be compared to the action of a wedge entering a block of wood; the resistance increases with every effort of the impelling power, in proportion to the increasing bulk of the wedge, spar, or bow. The small taper end is easily inserted, but as it is impelled onward, the resistance becomes greater and greater. Hence the power of the wedge, for splitting blocks, raising ships, &c.; the same obstruction is experienced if the small end of a tapering spar be towed foremost; the first resistance is scarcely perceptible, but as it progresses, the friction *increases* more and more, as the diameter of the spar increases; and towing becomes a toilsome affair. But reverse the position, and let the bluff end be foremost, the whole resistance, or obstruction, is met and overcome at the very outset; and the friction *decreases* every minimum of an inch after, as the spar tapers away aft. The wedge, applied as a power, derives its efficiency from resistance, and the small end

is placed foremost—whereas, the spar, or ship's bow, should derive its excellency from diminishing resistance, or friction; to effect which, the bluff end takes precedence. What can be more beautiful, or more efficient, in this point of view, than the bow of a Cork hooker. So much for velocity as attributable to false construction in regard to Steam Vessels; and the want of adequate propelling power, *which none of H. M. Steamers have.*

Secondly—"Consumption of fuel;" this is set down I find at 15lbs of coals per hour for each horse power of the engines. The expenditure of coals is dependent on various contingencies; viz., the kind of boiler used; the draught maintained; the construction of the flues; the actual pressure at which steam is worked; the effects of radiation; that is, whether counteracted by clothing the boilers, cylinders, and pipes, or not; the quality of coals; and the qualification of the stokers employed; so that the consumption may be 5lbs, or it may be 15lbs, per hour for each horse power; but the general average is from 8 to 12lbs. I myself found a difference of from 14 bushels an hour, to 7 per hour, with the same engines, but different boilers, and superior steam.

Lastly—"The proportion of horse power to tonnage of vessels." The first great and essential point in this respect, is the "build of the vessel;" for on *this*, and not

on tonnage, depends the power required. A log of wood, when hewn into shape, requires a very different force to propel it through the water, to that which would be necessary if continued in its original rough state. If then an approved form of construction can be propelled by a diminished power, it follows that the less the horse power, the lighter will be the weight of the engines on board; and consequently, the lighter will be the draft of water of the vessel containing them; and, of course, that the displacement to be overcome will be also less. Hence a long flat floor; bold bow above water, to counteract the plunging in a heavy sea, though as sharp as you will underneath; flaming out freely above the bends; good beam; and a clean run aft, will be highly advantageous. If we want a Steamer, we must build for a Steamer; if we want a sailing vessel, build accordingly: the first requires to be flat floored, and a light draft; the other sharp, and a good hold in the water.

Although we must be careful to give a power adequate to the propulsion of a Steam Vessel, we must at the same time be equally cautious that we do not overload her with machinery; the one is nearly as detrimental as the other. H. M. Steam Vessel Columbia, to wit, had originally a pair of 60 horse engines, which where exchanged for two 50s, after which, she floated lighter, went faster (that is, before she was fitted as a troop vessel, with a poop-cabin)

and consumed less coals. Mr. Laird, of Liverpool, says, the proportion of horse power should be *half* that of the tonnage; and instances 24 Steamers out of that port, of 371 tons each (average), whose power average 175; but the Steamers he had in view, were those on the old construction, and similar to the class of Admiralty Steamers spoken of above, intended for *sailing* as well as for steaming; indeed, some of them, when building, were constructed expressly with the intention of converting them into sailing ships, if the speculation, as *Steamers*, should not answer the views of the owners. Such vessels would, necessarily, require great power to force them through the water; and what is the consequence? the *weight* of one half of this machinery would require the *power* of nearly the other half, to overcome the displacement of water by the vessel's heavy draught; for the average weight of metal to horse power, in the construction of engines (though it differs according to the manufacturer), runs between one-half and two-thirds of a ton, or about 12cwt., and that of the boilers is about two-thirds the weight of the engines; add this to cargo, and what can we expect?

The most judicious system, then, in this respect, is to give Steamers machinery in the proportion of 50 horse power *engines*, but *cylinders* for 60^s, because we hereby conjoin lightness with efficiency; especially if applying steam "expansively," as we have the power of increasing

the effective pressure, and so causing the 50^s to work up to the power of 60^s or 70^s, a practice, as already noticed, not unusual.

With these various precautions, I have no hesitation in saying, that instead of one horse power for every 2 tons of measurement, a properly constructed vessel would be propelled full as fast, if not more so, with a power of one horse for every 4 or 5 tons of measurement.

I have thus endeavored to shew that individuals are no way yet agreed as to the power required for Steamers (the proper position of the paddle-wheels is another problem not decided either); otherwise we should not see such a contradiction, or vacillation, as to whether sixty, eighty, or a hundred horse power, is best adapted for the propelling of vessels of the same size and construction. If the power be not adequate to the vessel, she cannot attain the velocity commensurate with her actual capability; and, on the other hand, if it be more than just sufficient, the extra power is useless; because the wheels are proportioned to the performance of a given number of revolutions per minute; and they will not turn a whit the faster for having that extra power on an inadequate body, any more than would a road waggon, by the addition of an extra pair of horses, at a time that the usual team is competent to the work; unless, indeed, by forcing them they should

be compelled to quit their customary pace and get into a trot;—so with steam: by forcing it we may then bring this extra power into action, and increase the speed. But so long as we adhere to low-pressure engines, this would be an expedient too momentous in its probable results to be ventured on, without a corresponding necessity. But if the power be duly proportioned to the vessel, the utmost speed of which she is capable will be insured. And as the intention of Steam Vessels is for the more expeditious performance of certain duties, it cannot, one would imagine, be a matter of doubt whether each vessel, of the same dimensions and form, should not be fitted and furnished alike; the same propelling power being as requisite for the one as for the other. Yet we use them in all the varieties, of forties, fifties, and sixties, furnished to vessels of the same class and mould. Even for the more humble, though equally important tug boats, of the same dimensions, whose purpose is that of labouring against wind and tide, with a ponderous ship in tow; an equal power is necessary for each, provided their build be the same, in order to insure the fulfilment of their destined service with equal despatch; for otherwise, on whichsoever part there is a deficiency of power, it follows that the lesser must run a considerable risk, when towing a large ship in a tide's way, from the chances of being overpowered by the current operating on a weighty body dragging astern; or, if with a view of obviating that hazard, an increased

force is given to the steam, that increase of power, so gained, must be at the hazard of the boilers and engines, or cylinders; thereby placing both vessels in jeopardy at the same time. These remarks have referrence to low-pressure power.

A case in point may be cited in reference to H. M. S. Druid, when towed out of hamoze by the Echo; had one of the Steamers of less capability* been employed on that occasion, the Druid would, in all likelihood, have gone on shore under Mount Edgcumbe. Even with us it was incumbent to use the utmost strength, after the tide had taken her on the bow, in order to get her head round. A Steamer with low-pressure boilers, could not have done the same, as such boilers would be incompetent to supply any additional power of steam.

But were vessels, although belonging to the same class, of a different *form in construction* from each other, it would then be reconcilable that a greater or less power might be found adequate to propel each with equal velocity; the power being apportioned, of course, to the manner of form given to the Steamer for which it is destined. This result appears from the fact that the river Steamers

* From the use of expansive steam, and the power of increasing her force by throwing more steam into the cylinders; effected by merely opening wider the throttle valve of the expansive gear.

plying to Gravesend, &c., from having been lengthened, have gained speed, under the same engines, to a surprising degree. This arises as much from the circumstance of the paddles thereby becoming placed more towards the centre of the vessel than they previously were, as from the additional length, and consequently wedge-like form, coupled with an easy draft of water.

For *river work*, where passengers only are the object, and consequently a light draft of water, and there is a smooth surface to glide over, this does very well, and the long wedge-like form may be adopted in preference to any other; but were these vessels to attempt to cross the Bay of Biscay during winter gales, or were they destined to encounter a heavy sea, the same causes would operate with a widely different effect; for they would run themselves under water. Steam Vessels for general service, such as those belonging to Government, require a very different form* of construction; and unlike the sharp clipper built vessels of the river, must have a bow, not unsparing in fulness, well rounded, and flaming out boldly as it rises above the bends (but as sharp as you please under water), capacity for stowage, and not too great a

* It would appear most important that the bow should be adapted to divide the water with the least possible resistance, but experience has proved, that it is far more essential to facilitate the escape of the displaced water along the side of the vessel; hence a full bow is preferable—such is the difference between theory and practice.

draft of water; to insure which, she must have a long flat floor. Without a fullness of bow, she will have nothing to help her when pitching heavily during a gale; and unless a long flat floor, she will immerse too deeply in the water. A Steamer should glide over, and not cut through a sea; as, should there be a heavy swell, she would plunge deep, and not lift again in time to prevent the *following* sea from rolling into, and over, her; in which case, the probability is that she would founder. The Phœnix had a narrow escape of this kind, on the coast of Spain, in 1835 and 1836.

The next consideration is the position of the machinery; that of the cylinders has already been noticed; but in placing the paddle wheels, there is a difference in opinion; though for a vessel constructed as proposed, I cannot but believe that when the paddle wheels are placed *two fifths* of the vessel's length from her stem, that we have the vessel herself under the greatest command; because with a bold bow, she would not be liable to the same *dip* forward, after the paddles are put in motion, which the sharp built Steamers are subject to; and the counterpoise of provisions and water, &c. (not applicable to the river Steamers), would seem to require this position for them, to bring the ship on a proper line with the surface of the sea. This dip forwards, is found to average from six to eight inches, occasioned by the paddles; and when trimming the vessel,

regard should be had to this; for the nearer a Steamer is brought on an even keel the better.

In calculating the distances run by Steam Vessels, it is best to heave the log from the paddle box, the more effectually to clear the wake; and a deduction of one mile, in every nine, is found to be about the difference between the actual distance made good, and that shewn per log, in still water and light airs.

GENERAL MANAGEMENT OF STEAMERS.

On arrival in port, from a distant voyage, no time should be lost in overhauling the engines and boilers. The latter should be blown off without delay; and when sufficiently cold, to be examined thoroughly. In the mean time the engine-room will afford ample employment for the stokers, in clearing away ashes, &c., whilst the Engineers are scrutinizing the machinery. For the first week or ten days after the return from a voyage, the Engineer's crew should on no account be interfered with by the Officers on deck for the purpose of assisting in duties foreign to the engine-room; unless that it may become imperative to weigh the anchor, transport the vessel, or such like exigencies, which require the whole force of the ship's company. And, at all times, when their aid is required on deck, it would be advisable to send for the chief Engineer, and issue such order through him. Not that I purpose setting a distinctive mark between the two portions into which the crew of a Steamer must necessarily

be divided; but knowing, as I do, the duties the engine men have to perform, and that they have sufficient to occupy their time under a judicious Engineer, it could be wished that they be not interrupted, or broken off, from what may, at the moment, be under inspection, unless some urgent occasion arise. And as the Engineer himself must be the best judge whether such operations, as may be in hand, can with safety, or propriety, be delayed, consistent with the probable time the vessel may be required for service, the quantity and nature of the work to be done, the state of the weather, and the consequent exposure of the machinery thereto, &c., it is clear that he should be consulted prior to any appropriation of his immediate crew, different from their customary occupations. And, furthermore, by shewing this deference and mark of respect to that officer, it serves as an example to the men on board, who will the more readily look up to him as their superior in every point of view. Nor will he himself fail to appreciate such deportment from the officers; and will, in consequence, be ever ready to evince a disposition to accord with the wishes of those officers, on all occasions, wherein their views can be met without detriment to the machinery under his charge. One thing must never be forgotten, viz:—"that unless the engines are in perfect order, a Steamer is not in a condition for service." Unanimity expedites work, and we lose nothing by upholding the dignity of others.

By the official instructions, it is required to get the steam up once a fortnight, and move the wheels round, &c.; but, independent of this periodical movement, it is recommendable that whenever the men can be spared from other work, and the weather be favorable, the paddle wheels should be turned daily, by the united force of the crew, if but a few float boards only; with the twofold view of preventing, first, the corrosion of the iron; and next, the deleterious effects of wind and water, otherwise operating on a particular paddle, so situated, for perhaps days in succession. For should the piston rod remain in a fixed position for a length of time, corrosion in that particular part, where the piston rests against the cylinder, as also the rod in the glands, must ensue; for the packing gland insensibly eats away the piston rod, unless frequently moved. Wherefore, unless this movement of the sundry portions of the engine is occasionally resorted to, the pistons, more particularly, cannot be implicitly relied on as being thoroughly steam tight; and as they will, in such case, draw air from the glands, the vacuum, which should be as perfect as possible, becomes partially destroyed, and a general derangement of the whole machinery follows of course.

Whilst at sea, as the coal-trimmers will only be required occasionally to trim coals in the boxes, and as the number of seamen, attached to Steam Vessels, is but few, the

former may be embodied as a portion of the watch on deck; but when employed in the coal-boxes, due consideration will of consequence be had for them, in regard to exemption from deck duty.*

It is customary to get the ashes up from the engine-room every hour; which duty devolves on the watch on deck; the stokers filling the buckets below; for the engine men should not come on deck during the watch; not only because that their whole attention should be bent on the superintendence of their duties in the engine-room, but, moreover, in order to prevent any ill effects from a sudden transition to the open cold air, from the heated atmosphere in which they are working; and which must be detrimental, in a relative degree, to the state of the weather; whether wet, dry, frosty, &c. At sea the ashes are thrown overboard; but if in navigable rivers, harbours,

* Engine men are as liable to get on the doctor's list as the rest of the crew; it is therefore very hard upon such men to be disrated in order to allow others, who do their duty for the time being, to receive the pay. There should be an Admiralty order to place seamen, doing stoker's duty under such circumstances, on " check" as stokers or coal-trimmers, in the ship's books, and inserting the same in the log book; and they should receive pay for such duty, from the Dock Yards. But this regulation not to apply to the peculiar privileges allowed to Engineers and stokers on foreign stations, of double pay, unless they be permanently rated in actual vacancies. The disrating a stoker, in order to put an efficient man in his place, for the time being, is attended with many inconveniences, to say nothing of the injustice of adding privation to misfortune; for it is necessary to write to England in order that the allotment may be stopped. Were this regulation adopted, Steamers would never want for men.

&c., the impropriety of such a disposal of them is too apparent to need being cautioned against. In the latter case, if no "dust boat" shall come for them, they should be taken on shore, and deposited above high-water mark.

In getting coals on board, it was usual to send convicts from the hulks, to assist at such ports as have Royal Dock Yards. But where that assistance could not be procured, men from the shore were generally hired for the purpose, in the proportion of "two to shovel down the coals in the lighter, two to fill the bags, two to hold them open, three to whip up, and three as reliefs;" in all twelve persons. This arrangement usually is adapted at Gibraltar, Lisbon, and other foreign ports; and, as compared with convict labour, is far more economical, as well as profitable, in point of time. Woolwich and Chatham are now, however, the only Dock Yards infested with these pampered delinquents, whose very movements are characteristic of their moral dispositions,—being thieves of time; for their whole day's duty is not worth an hour's purchase.

SAILING A STEAM VESSEL.

Hitherto I have confined my observations to "steaming" only; but as our vessels are schooner rigged chiefly, or at all events furnished with sails, rigging, yards, &c.,

and can spread a large quantity of canvas, it may not be irrelevant to advert to the extent of the advantages to be derived from this aid; especially as most erroneous ideas on this particular point, have been, and I strongly believe still continue to be, entertained.

That "steam is our first great moving power" must never be lost sight of; and that "sails are but secondary, and subservient," is an equally important truth. We must therefore be cautious, that having recourse to the secondary power, we do not nullify, or dispossess ourselves of, the primary one. By this I would infer, that on the subject of "sailing a Steam Vessel" many persons suppose, that with a fair wind and fine weather, the fires may be dispensed with altogether, and the sails only* made use of. That this is practicable, there can be no question; but to effect it, would render expedient the unshipping of the float boards (or paddles), an expedient, dangerous in the extreme; for, as it is beyond human foresight to predict the moment of the coming storm, a gale may spring up when least looked for; and then what individual can keep his position in the paddle box, in order to replace the floats, and screw the bolts to? every

* H. M. S. V. Alban, Lieut. Kennedy, stowing only 8 day's coals, *sailed* from Barbadoes, July 1834, to Falmouth *in* 51 *days*; but was 7 days steaming out of it. It must, however, be observed that the Alban was one of the oldest form of construction; built on the scantling of a 10 gun brig, but having 15 feet more length.

lurch the vessel makes, immerses her wheels under water, broad side on; and at the moment the primary power is most needed, it is unavailable. An Officer would not be justified if, by such an act, he subjected himself to such a casualty; especially after experience* has demonstrated the ill effects. Besides, the unscrewing and the replacing of the paddle bolts, would render the nuts, by which they are secured, so loose, that no dependence could be placed in the certainty of having the floats attached to the wheels during bad weather; when, by the straining and working of the vessel, combined with the unceasing tremulous motion to which Steamers are subjected, every prospect would present itself of their being displaced, in consequence of such unscrewing and screwing. The bolts by which they are fixed cannot be too securely fastened.

There are, however, two cases in which a Steamer may be put under canvas only; viz.—running down the trades; or dodging about with a squadron; but speaking generally, there cannot be a greater falacy than to expect a "Steamer" to *sail only;* as it has been experimentally

* The Commanding Officer of H. M. S. V. Pluto, when proceeding to the coast of Africa, unshipped the float-boards, on starting from England, to save fuel; when arrived off the coast of Spain, he encountered a severe gale, blowing dead on shore, and he would gladly have reshipped his paddles had it been practicable; but every attempt was vain; and he narrowly escaped being wrecked; a slant of wind eventually enabled him to reach isle St. Mary, where he succeeded in getting them bolted to again, and reconnected the engines, after which he ran into Gibraltar.

tried, by several, and the results pretty much the same with all. H. M. S. Vessels Blazer and Meteor, in the Mediterranean, could get no more than from 4 to 4½ knots, under canvas alone, with the *lower float boards unshipped*, and all sails set; a good breeze, moreover, on the quarter; whereas, just before they were making from 8½ to 9 knots good. H. M. S. V. Medea's log shews from 3 knots to 4½ on a wind, as an average between 1835 and 1836, from 6 to 10 with steam and sails, and good breeze; and in a strong gale, on the 28th of August, 1836, under steam and canvas, 11½. In the other instance of running down the trades, provided the weather be fine, and from 6 to 8 knots can be made good under canvas alone, the fires may be extinguished for the first day or so; blow off the boilers, sweep the flues, clean the engines, and clear off the incrustation within the boilers, &c.; after this has been done, be content with only disconnecting the engines (on no account unship the float boards), and let the wheels revolve by the motion of the vessel through the water; keep a little fire backed up, so as to be in readiness in case of need.

H. M. S. V. Spitfire, left Falmouth, in February 1835, for Barbadoes; steamed for the first six days, and then got into the trades; disconnected the engines, and performed the remainder of the voyage under canvas; arriving out in 27 days and 6 hours. The same vessel returned in 36 days; having steamed 6½ days, on a N. E.

course; and then availed herself of a fair wind for the rest of the passage to England.

But the notion of "sailing" Steam Vessels, has been so predominant, that with a view to its accomplishment, several of the Government Steamers have been *overmasted.* It was this overmasting which caused the damage sustained by the Phœnix in December 1836, off the coast of Spain; being on a lee shore, with a very heavy gale from N. W., it became a matter of moment to secure an offing; to do which, the engines were put on at *full power,* or there was no chance; but being overweighted aloft, by her masts and rigging (though yards and topmasts were struck), she laboured so very much, as eventually to spring *four of her beams.* Had she been disencumbered of the top-hamper, she would have got to windward without such damage. Another instance presents itself in the Flamer; she went to Barbadoes, subsequently to the Spitfire, but took 44½ days to get out; yet she spread canvas enough, as compared to the latter vessel, having, besides her try sails, top and gallant sails, studding sails, jib, and stay sail; whereas, the Spitfire was rigged with lower masts only, and a bowsprit; but no jib-boom or topmasts; and during the stay of the Spitfire in the West Indies, the Flamer twice rolled away her masts.

If less than a 3 knot breeze for a *sailing vessel,* a Steamer will make no head way. H. M. S. Britannia of

120 guns, and the Meteor, Steamer, were in company in the Mediterranean, both under canvas, with a good breeze; Meteor's fires extinguished; the wind died away (the water perfectly smooth), and the Britannia passed her at the rate of 3 knots, whereas, the Meteor *stood still;* the wind not being powerful enough to overcome the resistence of the paddles, which had ceased to revolve. So long as the paddles go round, Steamers act *proportionably* well under favorable circumstances of wind and weather, with sails only; as they draw but little water, and have not much displacement to overcome: but they must not lay over, or the lee wheel being buried, more or less, in the water, will cause a proportionate resistance. But sails upon a Steam Vessel must ever be considered as secondary agents; they do not act like canvas upon a row boat, even when set; the oars of a boat serve only as a *propelling,* and not as an occasional retarding power, being raised out of the water after every stroke; consequently, as regards a row boat, each mile obtained by sails, as well as oars, is in addition to the rate gained by the latter; and that gained by the oars is in addition to the velocity obtained by sails. This arises from the alternate dipping into, and emerging out of, the water, of the oars; which consequently accelerate, and cannot impede, expedition. Not so, however, the paddles of a Steamer; some of which are *always* under water; and these act as a resisting power, destructive of the effect which would be

produced by the force of wind upon the sails, had the paddles not been there. At the same time it must be admitted that under certain limitations, with the aid of sails, we obtain the greatest speed of which Steam Vessels are capable.

The question as to how far Steamers are benefitted by a spread of canvas, may be illustrated thus; if the *paddles* drive the vessel faster than the *sails do,* it is evident that the sails (which in such case would hang loose as though becalmed) cannot add to her velocity? for it is the paddles alone which overcome the resistance of the waves.

On the other hand, if the force of the wind predominates over the power of the engines, and causes the *sails* to propel the vessel faster than the paddles, the paddles then must fall into broken* water coming from the bow, and meeting no resistance (by which alone they can act with effect) are not only of non-effect, but which is worse, should the wind be greatly predominant over the force of the engines, they must so fall into broken water in a *less rapid ratio* than that with which the bow passes through the water; and *thence* they become a retarding, instead of an accelerating, power.

* If the water from the bow passes aft with a velocity equal to that of the revolution of the wheels, the impelling power of the wheels would be quite lost on the water, for there would then be no friction, or resisting force, to overcome.

But if acting together, each exerts its relative influence on the vessel; that is to say, when the paddles (which to a Steamer, are the legitimate propelling power) are the predominant force, whereby impetus is given to her velocity, and the sails at the same time *keep full*, the latter serve *to relieve the labour of the engines;* and from that circumstance, do certainly contribute to the attainment, *during the continuance of the breeze* (at which time there is always more or less undulation in the sea) of that speed, which in a dead calm, her paddles alone would maintain, by enabling the engines to exert their full force, despite of the undulation of the waters. Whilst at the same time, a current of air would be thrown down from the belly of the sails into the engine room, and create a cool temperature there. So long as the sails keep full, they are beneficial; if not full, they act as a back sail and retard progress; but though full, they must not overpower the engines, otherwise the latter are a retarding principle. Furthermore, sails help considerably to steady the vessel.

Whilst on the subject of resistance, I beg further to remark that the progress of Steam Vessels is very considerably impeded by not allowing a sufficiency of egress from the paddle boxes, for the wind which is there accumulated; this mass of obstructing wind is engendered by the rotatory motion of the paddles within this pent up space, just in the same manner as that created by the fans of a

winnowing machine; the principle is the same in both. It is absolutely necessary that the paddles should be covered in, because if exposed to a gale of wind ahead, the power of the wind upon their surfaces, as they revolve, would be an additional obstruction for the engines to overcome; and fully equal to that opposed by the sea. With the gale abeam, the effect would still be great, though not so much so; and if right aft, the gale would cause the wheels to force the shafts, and perhaps damage the engines, wherefore it is necessary to cover them in; but unless egress be given to this wind, sufficient to *free the boxes,** it acts like a back sail upon the vessel. There would be no difficulty in drawing it off, and making it subservient to the purpose of disseminating fresh air throughout every part of the vessel; this in hot climates, introduced into the saloons and sleeping cabins, would be vastly beneficial.

Perhaps the following suggestions may not be unacceptable to such Officers as may be only recent in the command of Steamers; namely, that with the wind ahead, and not making more than two knots by steam, set the try sails to steady the vessel; keep the sails full (not minding the course to a point or so) and let the fires down (not out)

* Air tubes might be fitted to the upper edge of the paddle boxes; lead down and along the bulwarks, with supplimentary tubes, furnished with cocks, into the cabins; and the supply regulated according to the demand. By this means a certain and sure relief will be furnished during the most stagnant calms, when not a breath of air is otherwise stirring.

to ease the steam, until the weather shall prove more favourable* if she does not ride easy on one tack, try her on the other. This is with the understanding that there is no port at hand; if there be, by all means make for it. You will thus save time, labour, coals, and the wear and tear of machinery; as well as avoid the chances of breaking down through the forced exertions of the engines (though in every instance of the sway beam breaking, it is remarkable that it has always occurred during fine weather, and without any ostensible cause).

On no account attempt *forcing* the vessel by steam, during bad weather; as you may force her under water, instead of over it; and at all events will strain both vessel and engines; it is only in case of a lee shore that any such attempt ought to be made. Keep her at half speed only and under sail.

By keeping the fires backed up, you are always pre-

* If a strong gale and heavy sea, by all means put her under what canvas she can bear, and keep her one point off the wind, easing the engines at the same time; by so doing you avoid any seas breaking over the vessel, which (as is supposed was the case with the Erin) might swamp her; but it will glance off her bow and pass by. This expedient is the more applicable when the seas are heavy, but short, as in the Bristol Channel, where they follow in quick succession; for the length of a Steamer may preclude her rising in time to avoid the next sea, rolling towards her, from falling on board. By keeping her at half speed with the engines, there is no danger of losing headway; and, consequently, of being exposed to the tumble of the sea; which ought to slant off, as the bow pays off, by the striking of the billow upon it.

pared for getting steam up to the proper height, when it may be advisable to do so. If, however, at anchor, and you have occasion to suspect the safety of your position, get the steam up at once, to be ready to act if she drifts, and to keep her at her anchors. This precaution is the more necessary, as it requires four or five minutes to prepare the cylinders, by blowing through, and heating the steam jacket. If at sea, and it is required to get the vessel's head round, never wear her, if it can be avoided, especially in very bad weather; but if this must be done, get the stay foresail on her, give her full power of steam, and let her come round as speedily as possible; endeavour, however, to tack her first, as this will assist in bringing her round short. If, however, she will wear in safety, she will afterwards scud (if it be necessary) in safety;—the difficulty is in wearing. Avoid scudding if possible, the paddle boards impede velocity, as the *wind* is the predominant power; and a Steamer runs the chance of being pooped, as the wheels cannot turn so fast as the vessel would otherwise be driven through the water.

COASTING.

Whilst under weigh, should there be reason to apprehend danger ahead, and more particularly whilst navigating rivers, ease her; if necessary, stop her; if that will

not do, back her; but never pertinaciously persevere in driving through all, and content yourself with taking chance for the result. If required to turn in the shortest space, first give the vessel her full speed; put the helm hard over and stop the wheels; watch her, and by a judicious back turn she will come round short, on shifting the tiller.

Cases, however, occasionally arise in river navigation, wherein it is not possible to avoid collision, either with vessels, barges, or boats; as, for instance, in the pool, near the Tower, &c., owing to the very crowded condition in which such places are generally found; being surrounded on every side by one or the other. In such a dilemma the only alternative is to stop the wheels, and let the vessels close together as easy as possible, taking care to guard the sides and paddle boxes with fenders, and using every endeavour to boom each other off; after which, let the Steamer drift with the tide, but watch an opening among the vessels for escape, and, so soon as it offers, set her on at rather better than half speed, in order to insure a command of her.

The average state of weather, when making a voyage, is about two-thirds adverse, either as to bad weather, foul winds, &c.; otherwise sailing vessels would maintain their advantage over Steamers. But in light winds and calms,

or when foul but not boisterous, the latter have greatly the superiority; and, even in bad weather, they can generally hold their own. If on a lee shore, even though a Steamer may not be able to get to windward, she is, nevertheless, safe by letting go her anchor, notwithstanding it may possibly not reach the ground; for the weight of the anchor and chain will prevent her drifting, and she may be kept to her anchor by the power of the engines; taking care at the same time not to overshoot the anchor if it should have reached the bottom. H. M. Steam Vessel Comet, repeatedly, rode out heavy gales at single anchor: the Comet was on two occasions, when on the North coast of Spain, reduced to one anchor only; and on one of those occasions her only anchor, by which she was riding, was but a six hundred weight kedge, with the certainty, if unable to keep to it, of drifting, on one side, into the possession of the enemy; or, on the other side, upon the Bar of Bilboa.

If required to tow vessels in or out of harbour, provided the water be smooth and the breeze steady, it is better to lash alongside; but if blowing fresh, or in an open sea (especially with any undulation), the Steamer should go ahead, and tow with hawsers; the vessel which is being towed, however, to have those hawsers well attended,* so as to equalize the strain upon each, as the

* If towed by two hawsers, brought to the capstans (of the vessel towed),

vessels yaw about from time to time, or have occasion to vary the courses. She must, likewise, steer *directly after the Steamer,* and not be misled by any interference of pilots, masters, or others on board the vessel towed, otherwise the Steamer cannot be answerable for consequences. Always have, on board the Steamer, on such occasions, sharp axes lying alongside the bollards, to which the tow ropes are fastened; and do not hesitate cutting away, if the vessel towed is likely to get you into difficulty by not following directly after the Steamer; because her superior weight, if it once get the preponderance, will pull a Steamer round, and deprive her of all power to save or assist herself. The pilot should be on board the Steamer, and not on board the vessel towed, unless lashed alongside.

If small craft be the objects for towing, and there be several, breast them altogether close; if boats are in tow, go under very easy steam, or you will chance to swamp them, and, perhaps, drown their crews.

which they must be, there should be a careful hand stationed at the polls of the capstan; for should a sudden strain come upon one hawser, and the polls not ready prepared to catch and support the other, the capstan will fly round with great velocity, and to the probable serious injury of the men. This has frequently happened. And if the vessel towed does not follow in a direct line, her weight, acting on the quarter of the Steamer, drags her round, to the evident risk of both; especially in narrow waters.

CYLINDRICAL BOILERS, FOR EXPANSIVE STEAM,

As used on board H. M. S. V. Echo.

The advantages derivable from the introduction of cylindrical boilers on board the Echo, coupled with the application of steam on the principle of "expanding it within the cylinders" (and for which cylindrical boilers are indispensible), are so important that I am induced to enumerate a few of the more prominent, for the satisfaction of those who take an interest in the improvements taking place in steam operations, as, also, to undeceive others who have been misled by individuals who adhere to the *square boiler*, which is little else than a severe reflection upon science at the present day. I can have no personal interest in their adoption, and I certainly had every reason to be prejudiced against them, when first entrusted with the charge, on their being placed in the Echo; but I was resolved on doing justice to the parties who were interested, and to the experiment, notwithstanding that I incurred considerable pecuniary loss. Economy of fuel is admitted to be of momentous consideration; it is also allowed, that "the saving of steam constitutes a saving of fuel;" this being the case, it is not denied, even by the opponents to "applying steam expansively" (on board ship), but that steam of superior

elastic power conduces to this desired end of "economy:" but to effect it, renders *cylindrical* boilers absolutely necessary, because the common square boiler is incapable of sustaining a pressure adequate to that required for steam which is to be "expanded;" as such steam should not be under 15lbs per square inch, though it need not exceed 28lbs. It has already been shewn that steam, in a state of accumulation, doubles itself in every three minutes; hence, it can readily be inferred, that to increase the temperature, to any amount desired, it will not require much additional coals to augment it from the usual working pressure of 4lbs per square inch, or 225 degrees of temperature, to 15lbs, or 250 degrees; having attained this temperature, and, if it be admitted that it is "the tendency of latent heat to diffuse its caloric to the mass of fluid with which it is combined," it will not, I think, be denied, that to continue the steam at 250 degrees will not call for any extended increase in the supply of coal, but, on the contrary, will rather admit of a diminution; that, in fact, it will require but very little coal to maintain a sufficiency of fire-heat, to continue it at that temperature. Owing to the elastic power, or great capability of expansion, of highly rarefied steam, a small portion of it only suffices for the supply of the cylinder; wherefore, if instead of filling it, at every stroke of the piston, we admit but a quarter of the quantity which it can contain, and find that that quantity, on unfolding its volume, not only works

the piston with adequate effect, but, moreover, that as it expands, its temperature is so beneficially *reduced*, as to fit this, otherwise high-pressure steam, for condensation through the medium of the common condensing engines, we save, at each stroke, three quarters of a cylinder full, which is retained in a *latent state* within the boilers; and the demand for coals is, in consequence, proportionally lessened; and is such only as is necessary to keep the fires up, and not in a proportion requisite for raising steam. The saving of fuel is thus a consequence attendant on the saving of steam.

On board H. M. S. V. Echo, the working pressure was 15lbs per square inch, and the steam cut off at ¼ stroke, in a cylinder of 40 inches, and 4 feet stroke. The capacity of such cylinder is about 36 cubic feet; a quarter of which, 9 cubic feet, was the quantity of steam used each revolution, consequently there was a saving of 27 cubic feet of steam at every stroke of the piston, whether upwards or downwards; and as a 4 feet stroke makes 25 revolutions or 50 strokes up and down, there were 1350 cubic feet of steam reserved every minute; the latent heat from which contributed to diffuse its caloric to the supplies of fresh feed water, which was thereby speedily converted into vapour; and the expenditure of coals, which previously had been 14 bushels an hour, under the square boilers, was reduced down to 7 bushels per hour, or 140 tons a month saved!

It has already been noticed, that on Unity Mine, in Cornwall, this system has been productive of a saving in coals to the extent of 4000 bushels a month; that, upon the various other mines, has been much the same, notwithstanding the disadvantage of applying a new system to old engines.

That the first set of boilers, on this principle, should have been faulty, ought not to be a matter of surprise; and that they were so, I do not mean to deny, being about three inches too low; they should have had that difference of height above the flues; as that deficiency made "blowing off" an operation of some anxiety; because the great pressure of such superior steam, caused a very rapid diminution of water from the boilers, as soon as the blow off pipes were opened; and, owing to the rolling of the vessel, and consequent undulation of the water within, left it somewhat hazardous of blowing off too great a quantity at the time; in other words, we had but very little space to veer and haul on, when there was much motion.

Secondly, the cylindrical form given to boilers, insures durability and strength, which the square boilers cannot have; not only in regard to the well known properties of resistance, peculiar to an ellipsis, but, moreover, from the circumstance that this form induces a precipitation to

the bottom, in a line directly over the blow pipe, of whatever sediment there may be; for there is no flat surface on which it can settle itself; consequently, in this plan of boiler, that accumulation, so constantly found in the old, cannot take place; being carried off, while yet in minute particles, before incrustation can be formed. A further advantage is, that we have no smoke joints, as in the square boilers; the fire-flue consists of but one continuous passage for the smoke, &c., from the furnace to the chimney, no matter how frequently it winds backwards and forwards. So that we are in no danger of fire from the breaking of joints, or crumbling of clay.

Thirdly, these boilers being placed side by side, and not one before the other, are three in number, and communicate with each other by a connecting pipe, fitted from the front of the one to that of the other, with appropriate valves, to open or shut off the intercourse, at discretion; and thereby secure the proper feed, independent of the feed-pipe, which may, by accident, become choaked. We are thus enabled to work every boiler separately, or collectively, as may be convenient. One, two, or all, at the time, at option; putting out the fires of such as we may choose to economize on, or find it necessary to overhaul. With all three, the engines made twenty-four revolutions (a four feet stroke) per minute; with two boilers, twenty revolutions, and if reduced to

one boiler only, aided by the sails, good progress might be insured.

The following summary will shew the superiority of the cylindrical boilers, over the square boilers, at present in use: viz.—

They can be furnished at much less cost; Echo's were put in for £25 per ton.

They are much stronger, being seven-sixteenths of an inch in substance.

They are more durable, from not accumulating salt, in consequence of their circular form.

Are much lighter, and occupy less space in the engine-room, in regard to height.

Can be got at in every direction for cleaning; around, over, under, within and without, &c.

Require considerably less fuel.

Can admit of engines having cylinders of less diameter, 30 instead of 40 inch; and air-pumps the same.

Can propel the vessel faster; that is, can exert more power, in cases of necessity.

Can be filled without the aid of pumps, from lying so low as they do, in the engine-room.

Are free from the effects of cannon shot, for the foregoing reason.

Can be worked singly, or in unison, as necessity, or convenience, may render expedient.

Moreover, engines worked at high-pressure, are capable of either *increase* or *decrease* of power, as may be suited to the occasion; whereas, low-pressure engines cannot be so acted on. Whatever power is given the latter, that they must retain; wherefore, when there is no necessity for working the former up to their extent of power, or from whatever other motive, we may be induced to employ steam of low-pressure, there is nothing whatever to prevent us from loading the safety valves according to inclination, from 2lbs, up to 200lbs, pressure, as we may see fit. The great difference—and that which is so much the more in favor of the expansive application of steam—is, that any neglect, or inattention, in feeding the fires of low-pressure engines, whereby the steam may be let down, not only is the greatest exertion required to renew it, but that exertion must, likewise, be attended with a profuse expenditure of coal, before it can be regained. Not so on the expansive principle; a very moderate supply of coal will always maintain the steam at the proposed strength; and any temporary neglect may be remedied at a much less cost of fuel, because it cannot be rendered so inefficacious as to cause us to "lose steam," before such neglect is discovered. This has been demonstrated under the principles of "latent heat."

I have already made mention that on board the Echo, steam was applied on the expansive principle; and the safety valves loaded to 15lbs per square inch. I, more-

over, endeavoured to explain the principle of its action on the piston, (page 101) noticing, that only a small portion of steam of that, or any other superior, power, was adequate to all the purposes of efficiency. To regulate that supply, each engine is furnished with a separate valve, or, according to the phraseology,* "fitted with expansive gear," whereby this steam is admitted; and, afterwards, checked at any given point of the stroke, up and down; whether half, third, quarter, &c.; and that portion, not admitted within the cylinder, is retained in the boiler, being shut off and governed by the throttle valve in the usual way. The portion which is admitted, expands, and completes the full length of the stroke of the piston. These shut-off valves are placed just before the entrance of the steam into the jackets of the slide valves, with the throttle valves immediately before them.

Now with a view to the *double* action, which is necessary for the rotatory motion of the wheels of a steam vessel, it is requisite to introduce the steam into the cylinders, both at the top and at the bottom, in order to give motion to the machinery. To do this, the aid of the accompanying diagram may probably assist us in explaning; premising, as follow, viz—

* See page 100.

1 Is the starting lever, which is connected with the D slide.

2 The D slide valve.

3 The piston within the cylinder.

4 The piston rod and air-pump rod.

E The condenser.

F The hot water cistern.

G The air cone over the condenser.

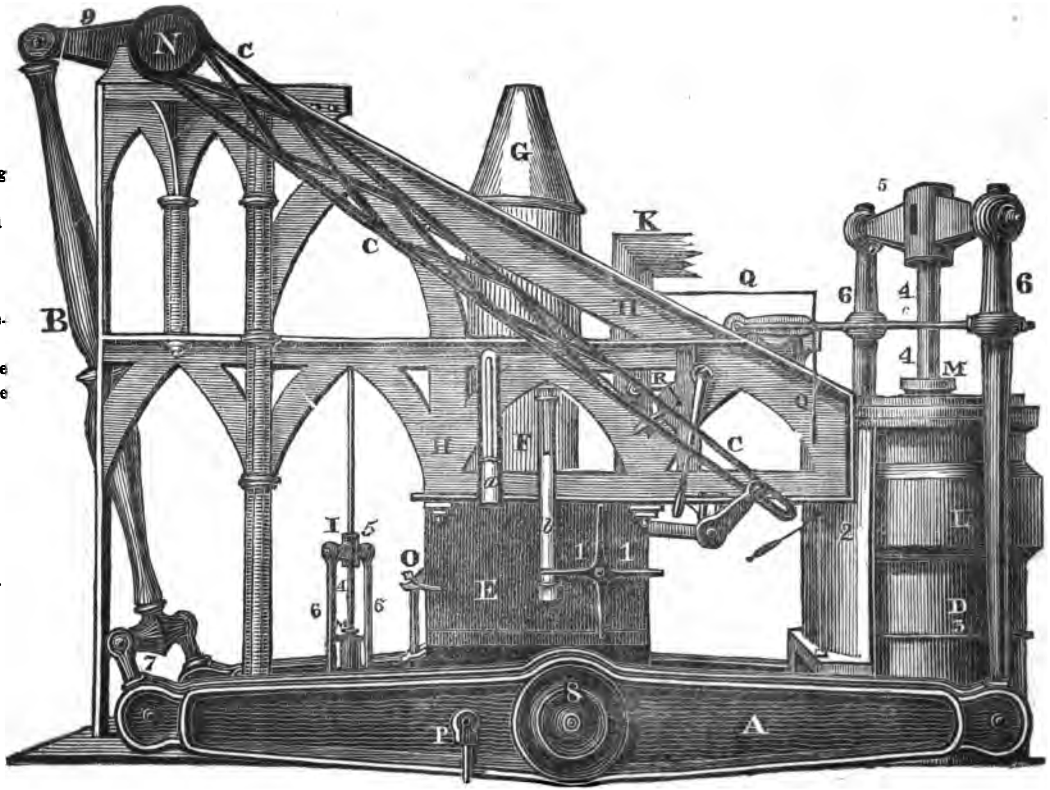
I The air-pump.

O The injection cock and pipe.

STEAM INTO THE CYLINDERS.

To effect this operation then, a lever, with a cross handle attached, called the starting lever, 1, which is connected with the D slide, 2, and which gives the impulse to the piston, 3, by the admission of steam into the cylinder, is turned; on which this slide moves upwards or downwards, as may be necessary, whereby the valves, through which the steam has to pass, are exposed, at the top or at the bottom, according to the position of the piston; the action of the one opening, causing the other to be shut off. This alternate action of the slide valves gives a corresponding admission for the steam; which if it be *at the top* of the cylinder, is *above* the piston; and

A Sway or working Beam
B Connecting Rod
C Eccentric Rod
D Cylinder
E Condenser
F Hot water Cistern
G Cone or Air-tube
H Frame of Engine
I Air-pump
K Steam Pipe
L Steam Jacket
M Stuffing Box
N Shaft
O Injection Cock
P Bilge Pipe
Q Expansive Gear
B Throttle Valve



1 Starting Lever
2 Slide Valve
3 Where Piston would be
4 Piston and Air-pump Rod
5 Cross Head
6 Side Rod
7 Fork Head of Connecting Rod
8 Pivot of working Beam
9 Crank of the Shafts
a Barometer
b Vacuum Guage
c Parallel Motion Rods
x Feed Pump
y Counterpoise of D Slide and Eccentric Rod
z Blow through Valve

MAUDSLAY'S ENGINE.

spreading over the upper surface of it, forces it to the bottom, following the whole way down in its descent; when there arrived, it passes into the condenser, E, through the hollow of the D slide (from the top aperture), by the opening of the foot valve, when the air-pump lifts at the mouth of the eduction pipe, and becomes water; a vacuum is thereby formed in the space which the steam had just occupied (*above the piston*); and this condensed steam, or water, together with what air may be within the cylinder is then pumped up, by the air-pump, I, and passes into the hot water cistern, F.

The vacuum being thus formed *at the top* of the piston, and the slide valve moving upwards, opens the lower aperture for the admission of fresh steam, *below*, that is, *under*, the piston, and there being no resisting power, in consequence of the *vacuum above* it, the piston is driven upwards in turn. As soon as this up stroke is completed, the steam, on the opening of the foot valve again, reverts back through the lower aperture, into the eduction pipe, and thence to the condenser; and the air-pump lifting at the same time, draws the water again from the condenser, and delivers it into the hot water cistern.

Thus when the piston rod is up, the D slide moves up also, but slower, and the air-pump goes down; at which time the foot valve is shut to the condenser, but opens the

moment the air-pump lifts, which it does on the receding stroke of the piston. The water from the hot water cistern is conveyed either to the boilers, or discharged into the sea by means of a pipe, leading through the ship's side, from the air cone, G, placed over the hot well. The cold water to be supplied to the condenser by the injection pipe, is regulated by a cock, O, as to quantity; and the usual temperature is rather above blood heat (see "Condenser").

In the diagram, the piston rod is ascending, and about two-thirds up; whilst the air-pump rod is descending, and about two-thirds down; the D slide is also mounting; the foot valve (this and the eduction pipe are hidden by the sway beam, A) is shut.

BLOWING THROUGH THE CONDENSER.

But prior to putting the vessel in motion, that is, to "starting the engines," the precaution of "blowing through the condenser"* is necessary, in order to free it from whatever air, or cold water, may be there; otherwise the steam from the cylinders cannot be acted on by sudden contact with the injection; and in such case the

* Not to be confounded with "blowing off the boilers," which is a different operation.

engines cannot be made to work, for the want of the formation of a vacuum.

To effect this, a valve is fixed, leading into the condenser, for the admission of steam from the slide jacket, whereby the water, or air, may be displaced; the manner of it is thus,—first, shut the condensing cock; then open all the valves to let the steam pass into the jacket, into the cylinder, through the eduction pipe, or outlet, into the condenser, and thence out at the blow valve; in order to expel the air and water from all parts, and thereby get them to a proper temperature. This will be shewn by the steam, eventually, issuing from the blow valve when all the parts are heated, the injection cock is opened and cold water let into the condenser, and a vacuum formed on one side of the piston, which produces instant action. The lever of the throttle valve should, on starting the engine, be held in hand by the Engineer, until the engine has acquired its regular motion; after which the D slide will be governed by the eccentric rod, C.

STARTING THE ENGINES AND PUTTING THE WHEELS IN MOTION.

The operation of "blowing through the condenser" being completed, observe the angle of the crank, or which

is equivalent, that of the *connecting rod;* if the slide be double, it is requisite to give it the same motion as that intended for the crank, up or down (if a *single* slide, an *opposite* motion to that intended for the crank is necessary for the slide). Thus, if the connecting rod rakes *aft* and a turn *ahead* be desired, the crank must have an *upward* motion, and the *slide* must have the same, to admit the steam on the top of the piston, through the throttle valve, which must be opened at the same time. The *eccentric* rod at the same instant is put into gear, by bringing the notch, at its lower end, over the pinnion of the traverse shaft, which works the slide valve. It is this rod which, afterwards, is to work the slide. Admit also a small quantity of water into the condenser, by gently opening the injection cock; this coming in contact with the steam, which now enters the condenser from the cylinder, through the eduction pipe, or outlet, and under the foot valve, produces a vacuum. The injection must then be increased to the degree of speed required.

EASING THE ENGINES.

In doing this, care is required to proportion the *continued* speed to the state of the weather; or rather to the condition of the waves; for should there be much sea on, and the paddles not revolve with sufficient rapidity to

overcome their resistance, a sea may strike them heavily, and, in all probability, break some of the machinery within the engine-room.

With this precaution, shut off the throttle valve, and, also, the injection cocks, in the proportion of power required to be continued; that is, a half, a third, quarter, &c. And to

STOP THE ENGINES,

Shut the throttle and injection valves altogether; and, at the same time, throw the eccentric rod out of gear by pushing it up, so that the notch shall be clear of the pinnion of the traverse shaft, and so stop the motion of the slide valve, which regulates the admission of steam within the cylinders.

ENGINE ROOM.

An actual "standard of expenditure" of engine stores cannot be established, as the expenditure of oil, tallow, fuel, &c. &c., is dependent on a variety of different circumstances, and varies widely on board different Steam

Vessels, even though they should be of the same class, same power, &c. As thus,—

Coal varies greatly in quality; some are friable, and readily go into dust on removal; these waste considerably. Others are hard, but slaty, and will not burn. Again, the *flues* within the boilers, and the draught of the chimney, if badly constructed, will cause a monstrous expenditure, which nothing short of a new set of boilers, differently formed in that respect, can check. Then the stokers vary in skill; one stoker will burn, at least, half as much more coal than another will, and after all not keep steam so well. And should the coals go into dust, from not being properly hand-picked, or screened through a, two or three inch mesh, riddle, a bad stoker cannot avoid letting it pass through the firebars, and these becoming mixed with the ashes, are thrown overboard to a very wasteful extent.

Oil must necessarily be used rather profusely; as the mechanism of the engine is altogether dependent on *constant* lubrication, even in the best fitted models. There are about thirty lubricators about the engines, including grease cups, &c. These a judicious Engineer will supply according to the length of voyage; if the Commanding Officer caution him that the projected trip is to be but short, he will then half fill the cups only; if, however, he

be ignorant on this point, he naturally *fills them up* to the brim; the consequence is, that when the vessel stops, all the surplus, beyond the actual consumption, is wasted. The same holds good, more or less, in regard to tallow, soap, &c. Badly fitted engines, ricketty, and loose jointed, will, of course, cause a profuse expenditure.

FIREBARS are destroyed frequently from not taking the precaution to shift their positions occasionally, as also to draw away the heated coals as they fall into the ashpit; if they are suffered to remain, the hot cinders underneath, acting in unison with the fire over them, melts the iron, consequently the weight of coals resting upon them, when in a state of fusion, bends, or even breaks them down, especially if of cast iron. Independent of this effect from want of caution, some coals are of a highly sulphurous nature, and this, alone, quickly destroys iron: again, a bad stoker maintains too strong a fire, and not only wastes steam, but coals also; and, at the same time, by the intensity of fireheat, burns out the bars.

And all other stores in similar dependance on circumstances. Now two-thirds of the Officers, commanding Steam Vessels, know nothing about the above facts; indeed many know but little, if anything, at all, about the engines, or engine-room, and, of course, know not how to control the abuses; they must necessarily be dependent

on what zeal and care the Engineer may choose to display. The following memorandum, however, will shew a general kind of average for the engine-room: viz.—

Average consumption of the Steamer's engine-room.

	In Harbour.		At Sea.	
	Per Day.	Per Week.	Per Day.	Per Week.
Coals........	According to quality; qualification of stokers; &c.			
Sweet Oil	5 pints	35 pints	1½ Gal.	10 gal.
Tallow	1½ lbs	10 lbs	20 lbs	140 lbs
Lamp Oil	1½ gal. the average for Sea and Harbour.			
Candles	½ lb	4lbs according to state of weather.		
Spun Yarn ..	......	......	......	10 lbs
White Oakum .	4 lbs	to	......	30 lbs
White Lead ..	1 lb	to	......	7 lbs
Red Lead	......	......	......	1½ lbs

SPARE GEAR FOR EACH VESSEL.

There should be kept at each of the following depots the undermentioned articles, one or two sets, which would be better than lumbering the vessels, particularly as the larger articles must be kept on deck, there being no room below for them; consequently they must be more or less exposed to salt water, and to the effects of weather.

Side Rods for Piston....................	2
Piston Rod............................	1
Air-pump Rod	1

Cylinder Cover	1
Side Rods for Air-pump	2
Bolts for lower end of Side Rods..........	4
Bolts for Connecting Rods	4
Connecting Links for Forkhead	2
Main Beam, or Side Lever	1
Drag Link fitted complete	1
Firebars of wrought iron, sets	1

To be deposited according to sizes, for 50s, 80s, and 120s, in Falmouth, Plymouth, and Portsmouth, on the Home Stations; and Malta, Gibraltar, Jamaica, Antigua, &c., abroad.

CASUAL ACCIDENTS INCIDENTAL TO STEAMERS.

CATCHING FIRE.*

This is an accident to which Steamers must necessarily be exposed, in a greater or less degree; but no apprehen-

* The accidents to which Steamers are exposed ought not to exist, as they are far more imaginary than real, provided only that common place precautionary measures be adopted. Yet the furnishing Engineers have, hitherto, shewn themselves but too regardless in this respect.—See article "Bilge Pipe," page 49, also "Safety Pipe," page 70.

sion need be entertained, as to any very serious consequences resulting; because the preventives on board Steamers are numerous. The hoses being screwed on, and brought into play where required, are worked by the Engines, without causing any labour to the crew. But with a view to obviate even this expediency, on placing the boilers in the vessel, see that care is taken that they be firmly fixed and chocked; so that the labouring of the vessel, at a future period, may not be apt to break the smoke joints; as in such case, not only may the flame pass through the aperture, but, should the firemen, when trimming the fires, chance to throw some of the hot cinders over the bridge of the furnace, they may fall through, and ignite whatever combustable material may happen to be near.

The same effect may arise from *damp coals*; which, sweating, often break out into flame. As a preventive to this latter accident, it would be advisable to fit *trap-hatches* along the gangways on each side, over the coal-boxes, of the width of four or five planks; with ring bolts attached. These may be caulked in; and yet made available in a few minutes, by the application of the caulker's screaving iron to the seams, and a crowbar to the rings; the coals could then be got at without risk of suffocating men, as at present, by sending them down into the coal-boxes. "Taking fire" is no uncommon

occurrence, from this cause (see note, page 64), viz. hemp, oakum, &c., if carelessly allowed to remain about, and, by accident, get in contact with oil, is very apt to ignite; wherefore, after cleaning the engines, the apprentice boys should look round and collect all such refuse. Vegetable substances, from damp, are apt to heat, and eventually to ignite.

SAFETY VALVES AND BLOW COCKS OUT OF ORDER.

In case of any difficulty in shutting the blow cocks, when blowing off, or any derangement of the safety valves, whereby the steam may get too high, before they can be remedied, let the fires be drawn immediately from under the whole, or such of the boilers as it may be thought requisite.

STEAM VESSELS APPROACHING BY NIGHT.

Repeated accidents having occurred, of the most fatal description, from Steam Vessels coming in collision with each other during the darkness of night, owing to the impossibility of determining the position of each other's head —or in other words, the courses on which each was running, the following suggestion is offered for considera-

tion, as a preventive measure against similar disasters in future.

Notwithstanding the customary display of lights, every one conversant with steam navigation cannot but be aware of the uncertainty of determining whether a contiguous Steamer is approaching directly towards, or even at right angles with the vessel he himself is in; or whether crossing obliquely, or if she be keeping nearly the same course as himself. To obviate this uncertainty, it is proposed that every Steam Vessel, whether Mercantile or Government, shall carry *three* lights at night to be placed in the following positions, and colored thus, viz. a bright *white* light at the *stern* (in order that no mistake may arise, as to whether the light seen, be from candles, &c., gleaming from the cabin windows; because this would make no difference, as to the fact that it is the stern which is seen); on the *larboard* quarter of the spread yard, another *white* light; and on the *starboard* quarter of the yard, a bright *red* lanthorn. Lights so placed, will at once determine the actual positions of the vessels, relative to each other;—the first essential fact will be evident, that a *red* and a *white* light denotes a Steamer, and not a sailing vessel. If she be right ahead, and *approaching*, only *two* lights will be discernible; and the *red*, determines which is her *starboard* side; if three lights be seen, it is clear that the vessel ahead has her *stern* to-

wards you; and that she is either crossing or steering the same course; if *crossing*, the *red* light being distinctive of her *starboard* side, determines the angle on which she is crossing. When *two* lights only are seen, she must be either abeam, or right astern; if *astern*, one will be *red*, the other *white*, at the spread yard; if right abeam the two spread yard lights will be in one, or very nearly so, and the stern light, in all probability, just visible, but will be known as such, from being so *low down;* if *three* lights be distinguished, those under the spread yard will be more or less open or acute; and the angle they form will determine which way her head is pointed.

The stern lanthorn must not appear *above* the taffrail; and it should be a standard one, similar to those fitted to flag ships. And the lights under the spread yard nine feet asunder, to insure their being distinctly visible, as well as to facilitate the calculation of angles, formed by the light, according to the positions seen in.

It should furthermore be established as a regulation, that two Steam Vessels when approaching each other, by night, should each of them *starboard her helm, before they actually near one another.* If this be impractible on the part of either, owing to shoals, &c., the vessel so circumstanced should stop the paddles, or if this be attended with hazard, ease them only, until they shall have passed.

UNNECESSARY WEIGHT OF STEAM ENGINES ON BOARD STEAMERS.

The great perfection of an engine consists in duly proportioning its various parts, with a solidity and strength commensurate with the work which each has, separately, to perform, *only* ;—a rule which manufacturing Engineers appear to have discarded altogether. Let any one examine the productions of the various manufacturers, and compare the work of each with that of another, and he will find the most extraordinary deviations,—not in the substitution of one mechanical movement, or lever, &c., for another,—for in this there is little or no deviation,—but in the *substance* of those levers. The side rods, the radius rods, connecting rods, &c., of one machine (on comparison of two of the same power engines, but by different manufacturers) will have a solidity of iron, in them, sufficient to build half the machine of the other manufacturer. They cannot both be right; and if the less ponderous of the two is found to possess strength sufficient, why should the vessel be burthened with the additional iron of the weightier engine? In the estimation of an Engineer, the engine ought to possess strength, combined with lightness, and that compactness without which strength cannot exist; a total dispensation of all superfluous ornament, because it adds weight; a simplicity of arrangement in its various rods, valves, &c., which shall admit of easy access at all

times, for the purposes of cleaning, or adjusting; and lastly, that which is most difficult to attain, a contraction of the whole frame, in point of dimensions, into the smallest space that ingenuity can devise.

The principal manufacturers patronized by Government are the Messrs. BOLTON and WATT, the Messrs MAUDSLAY, and the Butterly Company. The engines furnished by the last named, have the heaviest framing, whilst their connecting rods, side rods, &c., are not above half the dimensions of those of MAUDSLAY. On the other hand, Messrs. MAUDSLAYS' framing is lighter than BOLTON and WATT's, but their piston rods, air-pump rods, &c., are a great deal heavier. This is the more remarkable, as BOLTON and WATT make their air-pump bucket heavier than MAUDSLAY; and, what is equally singular, although they all differ in the above arrangements of engines, they appear to be united in setting their faces against the improvements projected by others. This conclusion is deduced from the fact that there is no material difference between the earliest and latest productions of those manufactories. The opposition to MORGAN's wheels, BARTON's pistons, and Echo's cylindrical boilers, are too well known to need recapitulation.

There are several alterations which may be introduced with considerable advantage;—why need we have a heavy

cast iron steam pipe, instead of sheet iron or copper? then again, the massive cone over the hot water cistern; if we must have it,—though there is no absolute necessity in the case, for the superfluous water, drawn off by the air-pump, may be forced through the bottom of the vessel, but if it must be there,—why not make it of sheet iron also?

BACKING ONE WHEEL, AND TURNING AHEAD ON THE OTHER.

The idea is pretty generally prevalent, that by such an evolution a Steam Vessel might be made to turn quicker, and in a shorter space than is at present accomplished. But this is erroneous: the advocates for this movement have attempted to draw their inference from the action of two persons in a boat, pulling in opposite directions on each side of her; and conceive that the same argument holds good in regard to the paddle wheels; which, however, is not the fact; for the oars, when pulling in counter directions, from their *length of projection beyond the sides of the boat* act as levers against each other; whereas the wheels of a Steamer, although placed on opposite sides, are fitted close in to the sides, and that also nearly amidships; and instead of the *angular* motion of the oars, sweeping from forward to aft, at one end, and from aft

forward, at the other, act in a direct line with the vessel, and with each other at the same time. Were the wheels, however, so fitted as that their inner rims, or circles, were of considerably less diameter than the outer, the paddle-boards would, in that case, have also an *angular* spread, though by no means proportionate to that given to the oars, in consequence of their extension; consequently their influence, when in opposition to each other, would be too slight to give effect to this evolution of turning the vessel, either quickly, or in less space, if it should even turn her at all; but this angular position of the float-boards, even if it had the desired effect in this respect, would deprive the vessel of velocity, for want of sufficient resistance.

In regard to the spread of the float-boards, another erroneous notion did prevail; namely, that the width of the paddle, spreading more surface of water, induced speed in proportion to the resistance so gained by its horizontal projection. But as there is a relative proportion for the length and breadth of the float-boards, in accordance with the power of the engine, so, if the diameter of the wheels be increased, and the paddle shafts risen in proportion, the float-boards may be narrowed to great advantage, and insure gaining thereby an increase in velocity. This practical advantage, in opposition to the above theory on resistance, was, I believe, originally demonstrated from the

casualty of a Steam Vessel, whose breadth of paddles, when endeavouring to pass the gates of a bason, during neap tides, caused her to stick fast; to prevent a repetition of the accident, the wheels were shifted, and others of increased diameter, and diminished float-boards, substituted; and on proceeding to sea, it was found that the vessel's speed was considerably augmented in consequence of the change. The calculation is, that the wheels themselves should traverse round at the rate of 14 knots an hour; in which case, the vessel when afloat, ought to make good two-thirds of that rate, provided that every thing is duly proportioned; one-third of the velocity, which the wheel would effect, when unobstructed, being lost by the resistance of the bow, coupled with the *want* of resistance for the paddles to act on, occasioned by their falling into broken water coming from the bow. Were it not that the weight of the paddle boxes would be an objection, they might be extended from the sides of the vessel, so far out, as to admit of the floats dipping into the sea *outside* of this broken water; and in such case the velocity of the vessel would be increased.

That speed is more dependent on the diameter of the wheels, than on the spread of the float boards, will appear from the following demonstration: say,

	Feet.		Feet.
Diameter of one wheel is	14	of another	16
	3		3
Circumference, about..........	42		48
Number of strokes per minute ..	24		24
No. of feet travelled per minute.	1008		1152

Consequently, as the engine is calculated to perform a given number of revolutions per minute, whether the diameter of the wheel be greater or less; so the greater, in the above example, gives a difference of 146 feet, as travelled over in each minute, above the smaller one. The paddle shaft must necessarily be raised higher from the surface of the water, in proportion to the diameter; and to determine this height, the lower float-board, when in a perpendicular position, should be fairly under water, with its upper edge just a-wash, when at the sailing draught.

To determine the position of the paddle shaft from forward, take 121 feet as the length of the vessel; one third of this, is 40 feet 4 inches; to which add 10 feet,=50 feet 4 inches, or rather more than two-fifths of the ship's length, from the fore part of the stem. Or, in the same proportion for another of, say 210 feet in length; one-third will give

70; to which add 20 feet, and we have the position from forward 90 feet, or somewhat more than two-fifths.

ENGINEERS.

Nine-tenths of the present men of this class, on board Steam Vessels, who pass under the appellation of Engineers, are mere engine men; the qualifications requisite to constitute an "Engineer" are such, as are not at all likely to fall within the attainment of, but few, of those now in charge of the engine-rooms of Steam Vessels; the rest are mere labourers, possessing some mechanical knowledge it is true, but without any pretentions to scientific attainments. Under such management, the superior powers of steam, are not likely to be elicited, beyond what is already known; and, be the adoption late or early, it will ultimately be imperative that Government select, men of education and scientific acquirements, for the service of Her Majesty's Steamers; for this branch of our profession is advancing daily for the purposes of navigation; and the merchants are holding out superior advantages in favor of this class of men, than are afforded in the Government vessels; several of whom have quitted the public service, and given a preference to the mercantile Steamers; a few have even quitted the country altogether,

and gone abroad. If it has been found expedient, in regard to sailing vessels, that the Officers who are invested with the charge of stores,—the masters of the Royal Navy, and the pursers,—should have a *rank** in the service, it will, likewise, be expedient that so important a trust as devolves on the Engineer shall, in like manner, attach adequate rank to the office; and surely no one can establish better claim to distinction than the man of liberal education and science. The present class of men must be retained; but a superior, or superintendent, in other words an "Engineer," must be added to the establishment. To obtain this latter class, it is only necessary that encouragement be held out for such individuals as can establish their claim for appointments, by a rigid examination† before competent persons, (to be selected by Government) in arts and sciences, in mechanics, mathematics, drawing, &c., whereby to entitle them to appointments; and, on joining their respective vessels, to hold rank similar with, and equal to, that of master in the Royal Navy; and the

* Royal Naval Engineers :—This department of the Naval service is in future to be so designated, according to a proposal made some time since to the Admiralty; and an uniform button ordered for the Engineers, their assistants, and apprentices, and to rank as Warrant Officers.—*Naval and Military Gazette, Sep.* 5, 1835.

† It has, of late, been customary to examine even the present class of men who are candidates for the rating of Engineers, after having served their apprenticeship; but the examination should be *open* and *public*, lest the examiner's (only one) good nature gets the better of his sense of justice to the service.

subordinates, or engine-men, to be placed in a class with the warrant officers. The education of such "Engineers" need cost Government nothing: as young gentlemen of family, whose means would admit of the expense, would gladly avail themselves of such an opening to establish themselves in a profession, and would study for that purpose. Not that I mean by this, that the opening is not to be general to all competent candidates; but that it affords the most eligible prospect of success; for have them we must, sooner or later.

I beg most distinctly to state that I disclaim all personality in any remarks I may have to put forward; but, at the present moment, constituted as the Engineer department is, not only we, the Commanding Officers, but the Government also, are absolutely the dependents, in many instances, on ignorance and arrogance on one hand; and designing persons on the other; for very many of those who hold the appointments as Engineers on board Steamers, illiterate themselves, but possessing a sufficient insight for the management of the engines, and seeing that we know less, if, indeed, anything at all, about them, assume an importance which, combined with ignorance, creates disgust; whereas the class proposed would cause, if established, such men to fall to their proper level, and render them truly serviceable. It is in vain to say "change them till you suit yourself;" for if an Engineer

be removed from one vessel he is sure to be placed in another; scarcely one among them is finally discharged; evidently shewing that competent men are not to be had in numbers sufficient to render us independent of the services of those, who for various reasons, may not be approved of. There are four classes of men which compose the greater portion of Engineers on board Steamers;—one set consists of mechanics whose acquirements are limited; these men are generally sober, respectful, and attentive; but incompetent to soar much above the drudgery of the factories; and, in consequence, can attain no conspicuous appointments on shore: Another class consists of characters whose abilities are great, but whose habits of inebriety, dissipation, and idleness, have caused them to be rejected from the factories. Surely the Government service should not be made the refuge for either of these classes, in the superior grade of "Engineer."

It is usual, and I believe generally understood, that the manufacturing Engineer appoints a person as the superintending, or working, Engineer of the vessel into which his machinery is placed; hence a third class. This, in appearance, seems reasonable enough; but, in reality, is highly detrimental, and disadvantageous to the public service, under the existing system of "repairs;" neither do we procure the best men, from the factory, as they are too valuable to be so disposed of. Was the manufacturer, in his

contract for the supply of machinery and boilers, also bound to keep the whole in repair for a specified time, say two or three years, at an *expressed sum of money annually*, this system would wear a different feature, and prove judicious; for he would then be scrupulous as to the competency and carefulness of the persons selected for the appointment, in the first place; and, in the next, would himself take care to have spare machinery always available, to replace any which may be defective, and take it in hand by times. This of course on the Home Station only, were it necessary, for instance, to give the boilers a thorough repair; instead of detaining the vessel for a month or six weeks in dock, and having his labourers working at a distance from his factory, he would at once replace those requiring repairs, by others; and get the damaged boilers on his own premises, and under his own eye; and thus would the Government Steamers be kept in a pretty constant state of efficiency. This system would probably prove, in point of expedition and expense, more advantageous than the establishment of a Government Yard for these purposes; because the work which would occupy a contractor in his own manufactory, a fortnight, could not be got out of the hands of the mechanics of the Royal Dock Yards under six or eight weeks; the *interests* of each operate in contrary ways; the former must accelerate his work, or he is paying labourers to a disadvantage; whereas, the mechanics

belonging to the Royal Yards, being paid by the day and not according to the work done, have an interest in prolonging the time for its completion; and if paid according to the work done, a boiler which requires some trifling repairs, is pronounced unserviceable by them, without getting a *thorough refit.* And who is to check this? the Admiralty Board are not themselves conversant with steam machinery, and are consequently under the control of the contractor, or other interested individual, who may, or may not, take advantage of their inability to say whether such and such repairs are requisite or not. How often do we see H. M. Steamers go into Woolwich Dock Yard, for the repair of some trifling defect, which the Commanding Officer has been obliged to report on; satisfied at the time, that within some forty-eight hours after, he ought to be at sea, as that would afford ample time for remedying; yet, to his surprise, he has received an order to *pay off* his vessel, that the machinery may undergo a six week's overhaul, and encounter expenses as enormous as they are unnecessary. If the same system existed among Mercantile Steamers, there is not a company existing, which would not long since have been bankrupt; but among them a very different plan is adopted; one, which is as summary as it is efficacious, viz., the ship's Engineer reports to the Commander whatever defect may have arisen; the Commander proceeds

forthwith to examine the nature of it with the Engineer whatever is required for effecting the repair, is immediately procured; and the mechanics of the engine-room set to work at once, and the vessel never detained in consequence. How different with us; in the first place we go into dock; after which we can have no voice in the affair whatever, as the Dock Yard mechanics are supposed to be the best judges; next succeeds a monstrous loss of time in forms of office, demands, references, consultations, reports, correspondence with the Public Boards, &c. And suppose (not that I mean to insinuate that such is, but that such a thing may be, within the verge of possibility) that a designing Engineer were a confederate with the man who placed him in charge of the machinery, and the latter under no compulsory obligation, by contract, to keep the boilers and engines in efficient repair at a stipulated expense, every time the vessel came under his supervision he must be adding to his gains.

But there is a fourth class of men among us as Engineers, who are distinct from the foregoing, men of talent and abilities; who finding no prospect of rising above the grade of foreman, in manufactories, for the want of capital, perhaps, are above that species of dependence, and prefer dedicating themselves to a life which affords a prospect of introducing them eventually in some

more favorable point of position. We have several such men still, though some have alienated themselves from the public service.

In regard, however, to the superior class proposed, if it be said that they will be "expensive;" let it not be forgotten that the engines themselves are expensive, averaging, at the first cost, from seven to twelve thousand pounds the set; and for subsequent repairs, *under the present management*, about five hundred pounds annually each vessel; but, under the superintendence of the proposed Officers, these valuable machines will be kept in the most efficient condition, by constant attention of *competent* persons, and the judicious remedying of any little defects which may appear, without going into dock, and incurring heavy repairs. Reference has already been made to the fact, that the *Firefly*, during the three years she was commanded by Lieut. Baldock, never was *detained under repair*, once during that time, so as to prevent her proceeding with the Mediterranean mails: can this be said for any other of H. M. Steamers *on the Home Station*? but the Firefly was exempt from visiting the Dock Yards. So, in like manner, the Alban, under Lieut. Kennedy, when absent in the *West Indies* during fifteen months, never cost Government one shilling for repairs of machinery; her own Engineers, and himself, acting upon the principle adopted in the Steam

Navigation Companies, did what was requisite, without consulting beyond their own engine-room. And that this was no chance circumstance of good fortune, in not wanting serious repairs, is clear from the fact, that the same Officer, was again on the same station afterwards, in command of the Spitfire Steamer, for twelve months, with the like result. Clearly shewing that under the surveillance of judicious Officers, possessing a knowledge of steam machinery, there is no necessity to be always having recourse to the manufactories, or to the Dock Yard mechanics, and subjecting their vessels to constant delays; this very same Officer, whilst on the Home Station, is repeatedly annoyed by detention at the Dock Yards. Beyond a doubt then, by the introduction of the proposed class of "Engineers," the machinery would be made to last, for years longer than at present, and that too without eternal patching; and the vessels be always in a state of readiness for service. So that ultimate economy, and not expense, must be the result of their introduction into the service; for it is not by the employment of the worst class of mechanics that we get work done cheapest, as it amounts to botching only; and we are compelled after all, to have recourse to the master hand. And what cheaper mode can we adopt in order to procure the most efficient, than that of contributing to a vanity which is inherent in human nature, by bestowing a rank on the individuals which will gratify a becoming pride, and at the same

time give a dignity to their station befitting a man of war.

It is an axiom in politics that "in peace we should make preparations for war;" wherefore, in conjunction with the foregoing, when we reflect upon the requisition this country will have, for numerous Steam Vessels, in the event of a war, every encouragement should be held out for advancing Steam Navigation in all its bearings, whether as regards the competency of those Officers who are to command them; or whether, in regard to the best means of economising fuel, &c.; for hereafter our convoys of trading ships will no longer be safe, unaccompanied by British War Steamers, as a part of their escort; others will be required as attendants on our fleets and squadrons; as also many for the conveyance of mails, dispatches, and similar services of expedition. It is true merchant vessels under convoy, may each take on board a proportionate supply of coals for their use during a voyage; but bad weather would effectually prevent that supply being furnished; together with other inconveniences, whilst at sea.

It would be judicious, moreover, that Officers who serve on board Steam Vessels, in junior grades, should have a preference of appointment to commands; this is the more desirable, as the taste for Steamers is by no means a pre-

valent one; that for sailing craft being greatly predominant; and most of those Officers who are in commands, evince this by their perseverance in the endeavours to make sailing vessels of them; but this cannot be; a sailing vessel is one thing; a Steam Vessel another; and each at variance with the other in form, build, and draught of water.

THE END.

CLASSIFICATION

OF

HER MAJESTY'S STEAMERS.

July 1837.

1st.

Cyclops
Gorgon

2nd.

Dee
Medea
Rhadamanthus
Phœnix
Salamander
Messenger

3rd.

Hermes
Firebrand
Firefly
Megera
Spitfire
Volcano
Flamer

4th.

Blazer
Tartarus
Columbia
Pluto

5th.

Lightning
Meteor
Confiance
Echo
Alban
Carron
African
Comet

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PARTS OF THE ENGINE REPRESENTED BY DRAWINGS.

G. POORE, Printer, Plymouth.